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The Milky Way*

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Research in the structure and motions of our galaxy has almost come to a standstill for the duration of the war. The galactic investigator has applied himself to the immediate task of helping to achieve victory. Telescopes and measuring engines have become idle and upon the halls and offices of some observatories there has descended a ghost-like quiet. All this is temporary, for we know that after the war we shall return to our observatories and take up again the never-ending task of sounding the depths of the universe. We cannot but regret the imperfections of mankind, which have brought about the murderous years of agony through which we are now passing. And yet we should not forget that from the point of view of pure research there are some definite gains. When, at the end of the war, we return to our chosen fields of research, we shall do so with new technical experience in related fields and we shall know how to build more effective telescopes and auxiliary equipment. More important yet, we should come back with a fresh approach to the problems of the universe, no longer weighted down by the pressures and commitments arising from researches already begun and in various stages of completion.

The selection of his first post-war project of research will be an important one for every individual scientist. It should be made deliberately and without haste, for everyone should realize that the opportunity to start anew comes only rarely. To plan more effectively, groups of scientists should meet, not to discuss the result of minor investigations already completed, but rather to lay the foundations for common research programs of the post-war era.

Planning for science has one thing in common with planning for the post-war order; neither can wait for the cessation of hostilities. The foundation for a successful post-war program of astronomical research must be laid while the war is in progress. The time to begin discussions is now.

The present paper represents an attempt to outline some possible modes of attack on the problems of our galaxy. To do this properly, we present first in brief an outline of our galaxy as it is generally accepted today. This we shall follow with a summary of the available data of observation relative to our problem. The remainder of the paper will deal with post-war plans.

*The fifth paper in the series of Astronomical Summaries.

The study of the Milky Way, its structure and its motions, has a special appeal not shared by many other fields of astronomical endeavor. Perhaps this is because on a fine, clear, summer night the Milky Way stands out as the grandest cosmic phenomenon. The problems of the physics of the stars and of the distant galaxies may then seem remote, but the Milky Way stretching across the vast expanse of the heavens is there as a first challenge to our desire for understanding the universe.

I. Outline of our Galaxy

The measurement of stellar distances has shown that our Milky Way system has great depth. Some of the stars which help to make up the visible band of the Milky Way are well within one hundred light years of our sun, but others are ten to a hundred times as far away. The

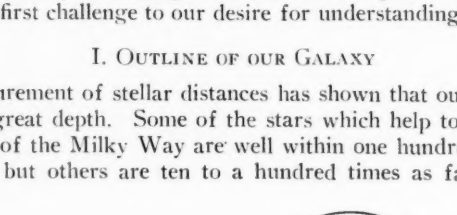

Figure 1
A Schematic Outline of the Milky Way System

Milky Way system is apparently a highly-flattened aggregation of stars, dust, and gas assembled in a wheel-shaped system. The sun is not centrally located in the system. Its position is indicated roughly in Fig. 1. We need not tell again the story of how Shapley used the globular clusters in first establishing the outlines shown in Fig. 1. It has been told many times, most recently in Shapley's own book "Galaxies."* Shapley's original estimate of the distance from the sun to the galactic center had to be revised downward when it became evident that there was considerably more interstellar absorption of star light than was supposed to exist twenty-five years ago.

The accepted value for the distance from the sun to the galactic center is 30,000 to 35,000 light years. It is almost certain that the latter figure represents an upper limit; figures as low as 25,000 light years have been mentioned as likely values. The somewhat larger value is supported by the data on the distribution of globular clusters. The wholly independent estimates from the theory of galactic rotation come closer to the lower limit.

*One of the Harvard Books on Astronomy, published by the Blakiston Company.

It is difficult to give an estimate of the overall diameter of our galactic system. The outline shown in Fig. 1 is a fair estimate of the boundaries of the volume which contains the majority of stars, nebulae, and clusters. There are, however, many known stragglers (stars as well as clusters, but apparently not many dust clouds or gaseous nebulae) that are found beyond the indicated limits. The tenuous halo around our galaxy extends in the galactic plane to well beyond 50,000 light years from the center. According to a recent estimate by Shapley, the overall thickness of the halo at right angles to the galactic plane is not less than 120,000 light years; the maximum diameter in the plane may be as great as 150,000 light years.

Estimates of the total mass of our galaxy are from 10^{11} to 2×10^{11} solar masses. The stars are responsible for about one half of the total weight of our galaxy; the other half being contributed by the gas and the dust combined. There seems to be considerably more gas than dust; the most reliable estimates suggest that the dust accounts for only 10 per cent of the total.

During the past forty years much progress has been made in the study of the motions of the stars in our galaxy. It has been found that the familiar solar motion of 20 kilometers per second toward a point in the sky not far from Vega (R.A. $= 18^h$, Decl. $= +30°$) represents only the effect of the sun's motion with respect to the nearer stars (within 1000 light years of our sun).

As might have been surmised from its flattened shape, our galaxy as a whole is in rapid rotation. The sun and the stars in its vicinity are whirled around the center of our galaxy at a fast rate. Until recently the accepted value for the velocity of rotation was 250 to 300 kilometers per second, with 270 kilometers per second being most frequently noted. It seems now that this value may be a little high. An investigation by Mayall on the velocities of the globular clusters has shown that the rate may be only 200 kilometers per second. A substantiation of the lower value would probably lead to a reduction in the estimated value for the total mass of our galaxy by a factor two.

The other observed regularities in stellar motions find a ready explanation in the theory of the rotating galaxy. In the radial velocities of distant stars, the familiar double wave in galactic longitude is interpreted as a consequence of a gradual decrease in the speed of rotation with increasing distance from the galactic center. Kapteyn's "two star streams" are shown to follow naturally for classes of stars that do not move precisely in the circular orbits prescribed by the simple theory of galactic rotation. The laggard stars that cannot keep up with the average speed of galactic rotation, shared by the great majority, are responsible for the observed asymmetry in stellar motions; the stars that move too fast in the direction of rotation have long ago escaped from the galactic system.

In the above paragraphs we do not pretend to give more than a rough

outline of the principal features of the structure of our galaxy. Some further details will be added in later sections. Before we proceed with the detailed analysis we should, however, point out that in effect little more than this bare outline is known with certainty about our galactic system. We are satisfied that the total dimensions and mass are tolerably well determined. Little definite information is, however, as yet available about the details of the structure of the system. The big problem on the post-war agenda will be to find out if our Milky Way system is really the huge spiral nebula which many astronomers suppose it to be.

There is no doubt that we are located in the outer parts of our galaxy. Many astronomers, including the author, are of the opinion that the sun is placed in a region where there is a slight excess in star density over the average for our vicinity. In other words, it seems as though the sun is in a minor spiral "knot." There is, however, another group that claims to have evidence to show that the sun is in a region of subnormal star density. If this were so, it might place the sun in between two spiral arms. We cannot say that we have begun to know much about local structure until we shall have succeeded in settling the question of the sun's place amidst the surrounding stars.

II. The Data of Observation

Reliable observations are the backbone of astronomy. Our theories on the structure of the galaxy can be no better than is permitted by the basic underlying observations. The lack of definite information about local structure, to which we have just referred, can be traced directly to our insufficient knowledge of individual and average distances for large groups of stars within two thousand light years of the sun.

The basic observational data for galactic research are, magnitudes, color indices, spectra, parallaxes, proper motions, and radial velocities. In the present section we shall survey briefly what data are already at the disposal of the galactic investigator and what are our greatest future needs.

Magnitudes and Colors. Fifteen years ago astronomers were primarily concerned with two kinds of magnitudes, photographic and photovisual. After several decades of careful investigation, led by Pickering, Seares, and Miss Leavitt, astronomers had by mutual agreement arrived at an international photographic and an international photovisual scale. At the first (Rome) meeting of the International Astronomical Union in 1922, the two standard international systems of magnitudes were finally adopted.

Apart from some slight corrections depending on the colors of the stars, a normal photographic telescope and standard blue sensitive plates produce magnitudes on the international photographic scale. When an appropriate yellow filter and isochromatic plates (sensitized to the yellow part of the spectrum) are used, the resulting magnitudes will be

very nearly on the international photovisual system; in color characteristics these photovisual magnitudes are not unlike visual ones, but they do not go so far to the red as the human eye.

Since the early 1930's we have witnessed the rapid rise of a third system of magnitudes, the photo-red system. The new plates developed at the Kodak Research Laboratory in Rochester, under the direction of Mees, have had a profound influence on photometric practice in American astronomy. The 103E and 103aE Eastman plates as well as the 103-Hα plates, have been used extensively for red work. For the yellow, photovisual, magnitudes, the older isochromatic plates have been replaced by the fast 1G's. For the near infrared the 1N plates have found some important uses. Special filters are available to limit the spectral region covered in each case, without too great a loss of speed.

The galactic investigator finds two principal uses for magnitudes:

1. Magnitudes on the international photographic scale (or some closely allied scale) are used extensively for purposes of sorting the stars according to apparent brightness. Star counts are customarily made in terms of these magnitudes. For purposes of statistical investigation, the stars of known spectral class are grouped according to their photographic magnitudes.

2. By a combination of photo-red (or photovisual) magnitudes and standard photographic magnitudes, valuable information is derived about the colors of faint stars. The color index of a star (photographic minus photo-red or photovisual magnitude) has become an important tool for research. It is especially useful in the study of stars of known spectral class, for which stars, from a comparson between actual and anticipated colors, we may derive valuable information about the "space-reddening" suffered as a consequence of galactic scattering of light.

Research in the field of magnitudes and colors is quite laborious. The basic work consists of the setting up of standard sequences for certain centers, well-distributed over the sky. The secondary type of research consists in the transfer of these standard sequences to any part of the sky and finally the derivation of the magnitudes and color indices of sometimes thousands of stars in the region under investigation.

Some of the more important available photographic standard sequences are the following:

1. The standard sequence near the North Celestial Pole, which is the basic one from which most others are derived.

2. The sequences of the Harvard Standard Regions, especially those of the twelve regions at $\delta = +15°$ (C-regions).

3. The photographic standards for Kapteyn Selected Areas 1 to 139 (north of $\delta = -15°$) published by Mount Wilson Observatory.

The North Polar Sequence is the most nearly accurate and most extensive of all. It covers the entire practical range of photographic

magnitudes. It seems unlikely that from the brightest stars down to photographic magnitude 17.5, the systematic and accidental errors can amount to as much as two or three hundredths of a magnitude. Beyond this limit the adopted scale needs further confirmation.

The standard photographic magnitudes of the Harvard Standard Regions cover the interval between $m = 7$ and $m = 13$. For the C-regions the revised photographic magnitudes, reduced to the international scale (see *Harvard Bulletin* 781, 1922, for corrections), are probably correct to well within one-tenth of a magnitude.

The Mount Wilson Catalogue of Selected Areas provides reliable standards between photographic magnitudes 12 and 17.5. For the brighter stars in the northern Selected Areas the photographic magnitudes are gradually becoming available through a joint undertaking between Harvard and the Kapteyn Laboratory, Groningen, Holland. These magnitudes, published in the volumes of the "Bergedorfer Spektral Durchmusterung," cover the interval $m = 7$ to 13, the same as for the Harvard Standard Regions.

For the photovisual magnitudes, the best available standards are those of the North Polar Sequence. As secondary standards the photovisual magnitudes in the Harvard Standard Regions serve very well. For the Selected Areas the available photovisual sequences are still quite fragmentary. With the advent of fast red-sensitive plates, the emphasis has shifted from photovisual to photo-red magnitudes.

Photo-red standards, for effective wave-lengths 6200 to 6400 Ångstroms, are now available for the region of the North Celestial Pole, the C-regions, and all Selected Areas at and south of declination —30°. The available standard sequences are largely the result of the work of the Gaposchkins at Harvard. In many ways the results are still of a preliminary character. At present the standards do not reach beyond $m = 13$ and even to this limit the possibility of errors of the order of one-tenth of a magnitude is not excluded.

For the standard photographic magnitudes, the crying need is for more and fainter standards in the southern hemisphere. In the extension of the standards special attention should be given to the Selected Areas south of $\delta = -15°$. Before the war Shapley and the Gaposchkins had planned a program for standards in the southern Selected Areas to be based on plates taken with Harvard's southern 24-inch Bruce refractor. The plates on this program, which have been slowly accumulating during the war, should go far toward providing working standards to $m = 17$ in the southern Selected Areas.

The second need is with reference to improved and extended red standard sequences for the northern as well as the southern hemisphere. For most purposes it would seem best to agree upon an effective wave-length somewhere between 6200 and 6400 Ångstroms as the standard for international photo-red magnitudes. A final decision should perhaps be postponed until we shall know what kinds of fast red- and infra-red

sensitive emulsions will be available after the war, but off-hand there seem many arguments in favor of not pushing farther toward the infra-red (*e.g.*, atmospheric bands).

In the post-war years the trend toward standards, distributed to supplement those at the North Celestial Pole, will probably continue. In many ways the region of the North Pole is a poor choice for the establishment of a standard sequence. For long-focus instruments the type of image on a polar plate is apt to differ markedly from the type found for other parts of the sky, where guiding errors have their effects. This circumstance renders the making of polar comparisons unnecessarily difficult. A further complicating factor is that overlying the region of the North Pole there is a veil of obscuration, which produces a marked reddening, varying with the distance of each standard star from the sun. Finally, the North Celestial Pole is not high enough in the sky for most observatories in the United States.

The C-regions and the Selected Areas (and perhaps also the E-regions at $\delta = -45°$) seem to offer suitable centers for the setting up of accurate photographic and photo-red standard magnitude sequences.

It is not possible to tell now what fundamental changes in the techniques of measurement of magnitudes and colors of faint stars will result from research carried out during the war. During the past fifteen years, magnitudes and especially color indices, determined with the aid of the photoelectric cell, have come to play an important rôle in galactic research. The work of Stebbins and his associates has provided us already with colors of great accuracy; without Stebbins' photoelectric colors, our knowledge of reddening of the light of distant galactic stars would not be anywhere nearly so detailed as it is today. The time may well come when magnitudes and color indices, determined by electrical means, will supplant photographic measurements.

We shall probably witness marked changes in the techniques of photographic photometry. The improvements in the construction of neutral filters and half filters will make it much easier than in the past to set up magnitude scales *ab initio*. A few photometric comparison plates of short exposure will probably serve to establish the zero point of a magnitude sequence in any part of the sky. From there on the sequence can be extended to very faint limits with the aid of one or more neutral half filters. If half filters are to be used extensively in this fashion, it will be doubly important to make available, at many well-distributed centers in the sky, accurate standards in the blue and red for stars between $m = 8$ and 13.

Improved telescopic equipment promises to be an important factor in post-war galactic research. We shall have several occasions to refer again to the great things expected from newly-built Schmidt-type telescopes. The Schmidt should prove very useful in magnitude work after the war. Its chief value lies in great penetrating power, a large field free from photometric errors other than slight vignetting, and a relative

FIGURE 2
THE HARVARD SCHMIDT CAMERA
The aperture of the spherical mirror is 32 inches, that of the correcting plate 26 inches.

freedom from color errors. The Schmidt should prove excellent for the transfer of a standard sequence to a neighboring center. Its great penetrating power and speed will make it about as easy to calibrate in the future to m = 18 as it was in the past to reach m = 13.

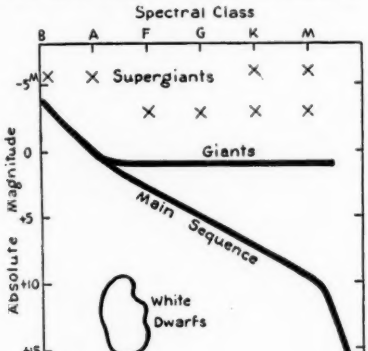

FIGURE 3
A SCHEMATIC RUSSELL-HERTZSPRUNG DIAGRAM
The diagram shows the relation between spectral type and mean (photographic) absolute magnitude.

Spectral Classification. The galactic investigator has a two-fold interest in spectral classification. With the aid of the spectra we can sort the stars roughly according to their absolute magnitudes; it is only by the use of stellar spectra that we are able to study the details of the structure of our galaxy. The second use of stellar spectra arises from the fact that, from the spectrum of a star, its true or intrinsic color can be deduced; the difference between the observed color index and this deduced color index yields information about the amount of space reddening suffered by the light from a particular star on its passage to the sun.

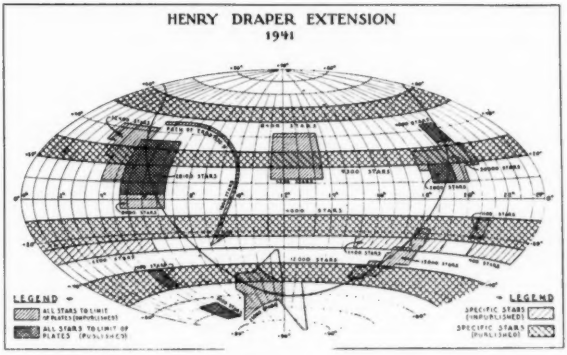

FIGURE 4
THE HENRY DRAPER EXTENSION (1941)
The chart shows the progress of the Henry Draper Extension as of the time shortly before the death of Miss Cannon.

The completion of the Henry Draper Catalogue of stellar spectra by Pickering and Miss Cannon provided us with an abundance of important data. The classification, which comprises altogether 225,000 stars, is complete to $m = 8.25$ in the northern hemisphere and to $m = 8.75$ in the southern hemisphere. Immediately upon its completion, Miss Cannon began work on the Henry Draper Extension, which reaches to well beyond the 11th magnitude.

During the past twenty years astronomers have tried to supplement the Henry Draper Catalogue in two ways. First, many efforts have been made to extend the classification to fainter limits. Secondly, much work has been done toward the difficult task of the development of more refined systems of classification in which the giants and dwarfs would be rigorously separated.

The Henry Draper Extension has already been completed for many special regions of the sky. After the war there will become available the "Cannon Memorial Volume" of the *Harvard Annals* with 100,000 hitherto unpublished spectra. Classification work has, however, been carried on by many institutions other than Harvard.

Noteworthy is the work of the Swedish astronomers. Led by Lindblad, astronomers at Upsala and Stockholm have classified the spectra of stars in a number of special regions. In this work a separation between giants and dwarfs has been successfully effected. Valuable results about the space distribution of the star densities have been obtained.

The observatories at Hamburg and Potsdam have completed the classification of the spectra of stars in regions centered on the Kapteyn Selected Areas. The observatory at Hamburg has already published, in cooperation with the Kapteyn Laboratory, the spectral types for the stars in Selected Areas 1 to 43; the results for Selected Areas 44 to 67 were about to go to press at the time of the outbreak of the war. The publication of the $\delta = 0°$ and $+15°$ zones is being held up only by the work on the photographic magnitudes. The spectral types for the stars in the Selected Areas at $\delta = -15°$ and southward have been published at Potsdam.

One of the most ambitious classification programs is that undertaken by Vyssotsky at McCormick Observatory. The principal aim of this program is to obtain spectral types and separation of giants and dwarfs for certain stars of which the proper motions have been measured at McCormick Observatory. Vyssotsky has photographed already the greater portion of the sky within reach from the latitude of Virginia.

The most striking advances have been made in research on giant-dwarf criteria for faint stars. In the early days of spectral studies the luminosity classification, by the methods of spectroscopic parallaxes, was limited to the relatively bright stars. It has been found possible to extend this luminosity classification to faint stars, if the dispersion of the spectra is not too small and if very special care is taken to produce excellent spectra. In this connection the work of W. W. Morgan of Yerkes Observatory points the way. Morgan has published an atlas of stellar spectra, in which numerous luminosity criteria are given for use on high-quality spectrograms with a dispersion of the order of 100 to 150 Ångstroms per millimeter. Morgan's classification was carried out on slit spectra, but recent work has shown that it will not be difficult to classify objective-prism spectra, if Morgan's criteria and type-stars are used as standards.

The future of spectral classification looks bright. The Schmidt camera is fortunately very well adapted for work on this problem. The very nearly identical foci for all wave-lengths produce spectra of uniform quality when the photographs are taken with an objective prism placed in front of the corrector plate. The sharpness of Schmidt images will serve to bring out distinctly the faint lines that are all-important for luminosity classification. The appreciable size of the usable field, and the reduced exposure times, make possible adequate coverage of a large area of the sky in a reasonable time.

To illustrate the effectiveness of the Schmidt telescope for classification purposes, it may be of interest to mention the recent successes with

the Schmidt and 24-inch objective prism at the Warner and Swasey Observatory. Dr. Nassau's plates show on 30-minute exposures excellent spectra to the twelfth magnitude. The increase in speed over older types of telescopes used for classification purposes is roughly a factor of ten.

After the war we shall probably have, besides the objective prism, the objective grating. Experiments by Wood at Johns Hopkins, Mount Wilson, and Harvard indicate that it should be possible to mount, and align accurately on a large disk, a mosaic of smaller gratings. If made permanent, these large objective gratings may well take their place beside large prisms.

The large reflectors will probably play an important rôle in future spectral classification projects. An 80, 100, or 200-inch reflector, fitted out with a focal-plane spectrograph, can photograph the spectra of faint stars, out of reach of the smaller instruments.

The classification of the spectra of faint stars, complete to at least the thirteenth magnitude, represents the No. 1 project for galactic research. Through the combined use of accurate colors and spectral types of faint stars, we should be able to advance rapidly our knowledge of the fine-structure of our galactic system.

Stellar Distances and Luminosities. The galactic investigator finds several uses for accurately measured distances of stars. Direct measurements of trigonometric parallaxes provide the basic material for the calibration of spectroscopic and spectral parallaxes. Our knowledge about the distribution of absolute magnitudes for a sample volume around the sun is based to a great extent on direct measurements of parallaxes. Much of our information about the mean absolute magnitudes of the stars of known spectral class is derived from trigonometric parallaxes.

The trigonometric method does not permit us to penetrate with much certainty beyond 300 light years from the sun. For distances up to 2000 or 3000 light years, valuable statistical information may be derived from proper-motion data. Mean absolute magnitudes, and dispersions around these means, can be found from discussions based on the proper motions and radial velocities of stars at intermediate distances. For the dwarf stars these represent a valuable check on the data derived trigonometrically; for the distant giant and supergiant stars these means and dispersions can be determined much better from data on the motions than from trigonometric parallaxes.

The luminous supergiants present a special problem. They are such a rare species that relatively few are found within 2000 light years of the sun. An analysis based on proper motion data suffers from the small size of the statistical sample. By the time that enough supergiants are included in a sample, we have reached stars at such great distances that their average proper motions are too small to serve as

useful indicators for distance. Fortunately the radial velocities come to the rescue. The effect of galactic rotation in the radial velocities increases proportionally to the distances of the stars. It begins to become appreciable at a distance of 2000 light years, where the proper motions begin to lose their effectiveness.

Galactic clusters play an important part in the estimation of stellar distances and stellar luminosities. For many of these clusters the distances are known accurately. The most effective method for estimating the distances of clusters is from a careful classification of the spectral types of all stars within reach of our telescopes. The estimates become especially reliable when a good portion of the main sequence of the Russell-Hertsprung diagram is observed. The several clusters in which supergiant stars are classified side by side with the giants and main sequence stars give us valuable information about the absolute magnitudes of the supergiants.

Our knowledge of the absolute magnitudes of the stars in the sample volume of our galaxy surrounding our sun is in a rather satisfactory state. It seems as though the trigonometric method of parallax measurement has yielded nearly all the information that it might reasonably be expected to give. It is doubtful if we can look for much additional information from this source for the stars that are intrinsically as bright as or brighter than our sun. Most of the work on trigonometric parallaxes will henceforth probably be concerned with faint dwarfs. This information, while vital to our knowledge of the intrinsic properties of the stars, will probably have only a limited application in the study of galactic structure. Absolutely faint stars will, however, provide excellent basic material for the study of the dynamical properties of the part of our galaxy near the sun.

From the point of view of the study of the structure of our galaxy, the two most important types of future research on distances and absolute magnitudes will probably be the following:

1. Further study of the absolute magnitudes of the highly luminous supergiants. In recent years the researches of R. E. Wilson on the absolute magnitudes of luminous giants have advanced our knowledge in this field, but much remains to be done. With the recent improvements in the techniques of accurate spectral classification (Morgan and others), it should become possible to increase the known number of stars definitely recognized to be supergiants. Studies of the radial velocities and color indices of these stars promise to be of great importance; they should also be investigated for variability.

2. Statistical studies of the mean absolute magnitudes and dispersions for separate spectral subdivisions. It is important that full use be made of the growing body of data on spectroscopic parallaxes. The work of Miss Hoffleit at Harvard and of Adams and his associates at Mount Wilson has in recent years added greatly to our information on

this subject. The material, used in conjunction with the data from the new precision classification of stellar spectra, should be subjected to a careful statistical analysis, based on proper motions and radial velocities.

Proper Motions. The December, 1943, issue of POPULAR ASTRONOMY carries an article in this series, by H. R. Morgan, on proper motions and stellar positions. We can, therefore, limit ourselves here to a brief mentioning of those researches in proper motions that are of special importance for a study of the structure and dynamics of our galaxy. We shall not touch again upon the problems of fundamental positions and proper motions, already fully covered by Dr. Morgan.

Until 1930, so-called relative proper motions played an important rôle in galactic research. By these are meant proper motions measured relative to the "average" for the area. Relative proper motions were used for the study of star streaming among the fainter stars. From these studies it has been shown that star streaming is not a purely local phenomenon, but that instead it prevails generally to distances of at least two or three thousand light years from the sun.

Relative proper motions, however, can not give any information concerning the effects of the rotation of the galaxy, since the first-order rotation terms in the proper motions are independent of the distance from the sun. From relative proper motions we obtain only very indirect evidence concerning the effects of the systematic displacements caused by the sun's motion with respect to its neighbors. At best relative proper motions would yield an estimate of the difference in average displacement for groups of stars with different magnitudes. Slight errors in the measured proper motions would, however, frequently mask these small cosmic effects.

During recent years the emphasis has, therefore, been placed on the derivation of absolute proper motions of faint stars. To indicate the variety of approaches in this field of research we present here briefly three totally different methods for obtaining absolute proper motions, *i.e.*, displacements measured with respect to a fixed reference system.

1. In Germany, under the supervision of the Astronomische Gesellschaft, and by Schlesinger and Miss Barney at Yale, absolute proper motions have been measured for thousands of faint A.G. stars. For each region of the sky one or more photographic plates are taken. On these plates the positions of the A.G. stars are measured relative to a small number (say 25) of comparison stars. For the comparison stars the absolute positions and proper motions are determined with the aid of meridian circle measurements and the photographic positions are thus reduced to absolute right ascensions and declinations. The proper motions are found by comparison between the old (meridian circle) A.G. positions and the new photographic positions. Researches of a similar character are under way at the observatory at the Cape of Good Hope.

2. An extensive program for absolute proper motions of faint stars has been carried out at the McCormick Observatory by Alden, van de Kamp, and the Vyssotskys. In this program the proper motions of faint field stars are measured relative to that of a Boss star of known proper motion, centrally located in the field. By correcting the relative proper motions of the faint stars for the effect of the known motion of the central star, the absolute proper motions on the Boss system are obtained for the faint field stars. The McCormick programs have already yielded important information about secular parallaxes, star streaming, and galactic rotation. During recent years they have taken on an added significance by the determination of the spectral types of the field stars by Vyssotsky, and the measurement of radial velocities of a considerable fraction (1000 stars in all are on the program) of the field stars by Edmondson from plates taken at McDonald and Mount Wilson Observatories (plates at Mount Wilson taken by Mitchell).

3. An important program aimed at the derivation of proper motions for very faint stars is under way at the southern station of Yale Observatory. In the A.G. repetitions the limit is not far from the 10th magnitude. In the McCormick programs stars to the 12th magnitude are included. In the Yale program it is intended to derive absolute proper motions to the 16th magnitude for the southern Selected Areas. A 5-inch camera with grating attached gives photographs that make possible the measurement of absolute positions on the Boss system, for stars to $m = 11.5$. A second series of plates taken with the 26-inch photographic refractor, again fitted with an objective grating, provides the material from which the positions of stars to $m = 16.5$ may be determined in the system of the fainter stars on the plates taken with the 5-inch camera. Since, for the stars to $m = 11.5$, the positions have already been derived on the Boss system, the tie-up between the 7th or 8th magnitude Boss stars and the 16th magnitude field stars will have been achieved. Proper motions on the Boss system can be derived by repeating the entire program after a suitable lapse of time.

It is clearly shown in Morgan's survey article on positions and proper motions that, because of numerous sources of systematic errors, it is quite difficult to obtain reliable absolute proper motions for faint stars. The current procedure is to consider the reference system of the brighter stars as the basic one, to which all proper motions of faint stars are then reduced. This should not continue indefinitely. In the long run it should prove much more satisfactory to measure directly absolute proper motions of faint stars and then reduce the proper motions of the bright stars to the system of the faint stars. To achieve this it has been suggested that the positions and proper motions of the faint stars be tied to the system for the faint external galaxies. Our present aim is to obtain a fundamental system of proper motions accurate to within 0".001. The faint, almost star-like, external galaxies are all at such great distances from the sun that their cross-wise motions

will at most be only a small fraction of this amount.

It must not be thought that the external galaxies will bring about an easy solution for the problem of establishing an accurate fundamental reference system of proper motions. The photographs which show the galaxies best are generally of long exposure; the attainable accuracy of measurement is not anywhere nearly so great for such plates as for the short-exposure plates customarily used for the measurement of positions. Guiding errors will probably prove to be a real source of difficulty when it comes to comparing the positions measured for the point-images of the stars with those of the finite disks of the galaxies. If we succeed at all, we shall at first be able to measure absolute proper motions only in a few regions of the sky. It will be necessary to select fields rich in galaxies, or fields centered upon larger nebulae showing numerous well-defined spiral knots. The task will be arduous, but it will be well worth the effort if we can succeed in establishing the beginning of a reliable absolute reference sytem for stellar motions.

Radial Velocities. Since the turn of the century radial velocities have played an important part in the explanation of the motions and dynamics of our galactic system. Originally they contributed basic information relating to solar motion and star streaming. The radial velocities of globular clusters have provided us with the best evidence to show that the sun and its stellar neighbors are moving around the distant center of our galaxy at a rate of at least two hundred kilometers per second. It should be realized that our confidence in the theory of galactic rotation is founded almost wholly on basic radial velocity material. The evidence from the proper motions is indefinite and the spectre of possible systematic errors is always plaguing the investigator. In the radial velocities of the distant O and B stars and of the Cepheid variables, the evidence for the Oort-effect, progressing roughly in proportion to the distance of each star group from the sun, is unmistakably present. Without adequate stellar radial velocities, galactic research would be in a sorry state.

In the years preceding the outbreak of World War II, the Lick, Mount Wilson, Yerkes, Victoria, David Dunlap, and Simeis Observatories had been adding steadily to the world's supply of stellar radial velocities. Stars of all types and varieties had received their share of attention. The most important contributions were made through the radial velocities of distant O and B stars, Cepheid variables, R and N stars, and galactic clusters. No so spectacular, but definitely of a basic character, were the important new lists of radial velocities of stars within 1500 light years of the sun. The radial velocities of faint A stars, for example, have not only given us new data for the study of the local characteristics of stellar motions, but they make possible a more refined type of analysis than was hitherto possible of mean absolute magnitudes and dispersions around the means for special narrow spectral subdivisions.

At present our knowledge of radial velocities for stars brighter than the sixth magnitude is nearly complete. For the fainter stars our information is still quite incomplete.

After the war there will undoubtedly be much activity in the measurement of radial velocities of faint stars. At all of the observatories mentioned above, the radial velocity programs have included special lists of faint stars. These lists are no longer confined to stars known to be at very great distances from the sun. It is being realized that, for an understanding of the local characteristics of the distribution of stellar motions, we need a knowledge of the radial velocities for a fair sample of the run-of-the-mill stars, dwarfs as well as giants. The F to M stars in the galactic polar caps are coming in for their share of attention, for it is being realized that our rate of progress in probing distant galactic regions may depend on the status of our information about the star-empty regions near the poles of our galaxy.

One of the most intriguing radial velocity projects that is now in progress of execution is the measurement by Edmondson at Indiana of the radial velocities of 1000 of the faint McCormick proper motion stars ($m = 10$ to 12!), a program to which we have already referred briefly. It is encouraging to see that with modern spectroscopic equipment, attached to large reflectors, 12th magnitude stars are within reach.

Radial velocity work does not necessarily need to be confined to large reflectors and slit spectrographs. An investigation by Bok and McCuskey has shown that, with the 16-inch Metcalf refractor at Harvard, and an objective prism yielding a dispersion of about 100 Ångstroms per milimeter, it is possible to obtain radial velocities with probable errors not exceeding $\pm$ 10 km/sec for the mean of four plates. The reduction of the measurements and a discussion of several hundred unpublished objective prism radial velocities were interrupted by the war. The present status of the problem of objective-prism velocities is as follows.

With the 16-inch Metcalf, measurable spectra can be obtained to photographic magnitude 9.5 or 10, with $m = 9.2$ as a limit for results of highest attainable accuracy. The spectra are about half a millimeter wide and, to be satisfactory for measuring purposes, they should be equal in quality to the spectra used for precision classification purposes. A liquid filter with neodymium chloride provides the terrestrial reference line. The dispersion of 100 Ångstroms per millimeter seems to be the optimum one for work of this sort. A loss of accuracy results if a smaller dispersion is used and, for the A-type stars, there is no appreciable gain in accuracy by the choice of a greater dispersion.

The effective limit $m = 9.5$ offers the most serious objection against planning further large programs with the 16-inch Metcalf refractor. At that limit, one finds in only a few regions of the sky a sufficient number of stars per plate to make the effort of measuring the plates wholly worth while. Efficient slit spectrographs attached to the large reflectors

can now reach ninth magnitude stars in very short exposure times. The limitations of the neodymium filter (one reference line only and a blend with an iron line, which prevents the use of the method for G, K, and M stars) seem to make it inadvisable to extend the work with the 16-inch beyond what has been undertaken.

The use of the objective prism (or mosaic grating!) holds, however, great possibilities for the mass measurement of radial velocities with the aid of the new Schmidt cameras. There is little doubt that one should aim at using a dispersion of 100 Ångstroms per millimeter, though, because of the excellence of the Schmidt optics, one might succeed as well with a dispersion of only 150 Ångstroms per millimeter. By the use of fast emulsions, and with a full-aperture prism, a 24-inch Schmidt should be able to photograph, with a neodymium filter, the spectra of stars to at least the 11th magnitude. With larger apertures, correspondingly fainter stars might be reached.

The gain of a limit $m = 11$ over $m = 9$ is enormous. Not only are much more distant stars reached in this way but, most important, the number of measurable spectra per plate is increased about five-fold on the average. Several suggestions have been made for a reference for zero-velocity, different from the neodymium line. So far none of these have been applied successfully, but there are hopes that after the war real progress can be made. If it should become possible to develop a method which would halve the plate error and increase the attainable magnitude limit by one-half or three-quarters of a magnitude, then the objective-prism method would emerge as the most powerful method for obtaining stellar radial velocities.

A brief survey of current radial velocity problems would be incomplete without a mention of the urgent need for radial velocities of stars in the southern hemisphere. In the past the leading radial velocity observatories have operated mostly in the northern hemisphere. The Lick Observatory operated a station in Chili, but this was closed at the conclusion of the program for bright stars; the observatory at the Cape of Good Hope also discontinued its work on radial velocities.

The lack of adequate radial velocities for the southern hemisphere is appalling. It is felt to some extent in all studies involving stellar motions, but more seriously so in research related to the rotation of the galaxy than in any other field. Adequate velocity data are lacking for a full quarter of the galactic circle. It happens that the neglected quarter contains some of the finest regions of the Milky Way, including the Carina region with a superabundance of O, B, and A stars and Cepheid variables.

Fortunately there is every indication that the deficiencies for the southern hemisphere will soon be made up. The Radcliffe Observatory at Pretoria will have excellent spectrographic equipment and the new observatory at Bosque Allegre in Argentina is intending to enter as well into radial velocity work. An objectve prism program should be

started when powerful Schmidt cameras and good objective prisms or mosaic-gratings become available for research on the southern skies.

(To be continued)

Experimental Moon Craters

By WILLY LEY

The idea that the so-called "craters" of the moon, in spite of their customary name which implies volcanic origin, are really the results of the impact of meteoric matter, originated during the nineteenth century. The first astronomer to suggest such an origin seems to have been Franz von Paula Gruithuisen of Munich, a strangely named man who was somewhat strange in various aspects and who is famous in astronomical history mostly because of his fantastic explanation of the luminescence of the dark portion of Venus and for his alleged discovery of a "ruined fortress" on the moon. But the theory did not find wide circulation in astronomical circles until R. Proctor and others began to adopt it near the end of the 19th century.

Meanwhile a practical geologist, the *Bergrat* Althans, had not only arrived at the same conclusion by observing the results of the impact of projectiles on armor plate, but had also tried to furnish experimental evidence. In about 1845 he began dropping balls of grapeshot into flat and shallow pans filled with fresh mortar. It seems that he, as indeed one may by this method, obtained a few speciments of fair resemblance to the objects seen through the telescope. But the percentage of "useful" results must have been small, since by repeating the experiment I found that only one in six or seven might conceivably be exhibited as a "model" of a lunar "crater."

Other experiments, made by various astronomers and geologists during the period from about 1880 to about 1910 were rather similar in nature and produced as little encouragement as those of Althans. While the experiments failed more or less miserably other evidence which spoke strongly in favor of the meteoric hypothesis, was accumulated, with Meteor Crater in Arizona heading the list of comparable objects.

Obviously the inability to produce small models of meteoric craters by experiment did not prove anything. It was not the theory that was useless but the experiments. Small bodies hitting the surface of a "batter" of Plaster of Paris or cement obviously could not produce results similar to those produced by large bodies of iron or rock hitting a rocky surface, especially since the velocities in one case could be assumed to amount to many miles per second while they were hardly more than three feet per second in the laboratory.

It was in 1918 that the problem was approached from this point of view by the geologist, Dr. Alfred Wegener, who later became famous as originator of the geological hypothesis of continental drift. During the

years 1918 and 1919 Dr. Wegener performed a number of experiments in the laboratory of the Department of Physics of the University of Marburg which had the purpose of eliminating the difficulties inherent in the experiments of the type first performed by Althans. The results of his work were published in the form of a small paper-covered book of only 48 pages in 1921 by the publishing house of Friedrich Vieweg & Son in Braunschweig under the title *Die Entstehung der Mondkrater.* (The Origin of Lunar Craters.) As far as I know it has never been translated into any other language and has remained virtually unknown in the English speaking world.

FIGURE 1

Model of an impact crater measuring 10 cm in diameter. This, like all other model craters, was produced by dropping a soup-spoonful of powdered matter on the surface of a layer of cement powder, 2.5 cm thick. The height from which the powder was dropped was one meter, the picture was taken vertically from the same height, the tray with the model was placed in the shade and illumination provided by sunlight reflected by a plane mirror.

Dr. Wegener's reasoning began with the realization that earlier experimenters had failed to pay enough attention to the type of physical forces coming to the fore in their work. In general one may distinguish between "molecular forces" (in these experiments mainly the strength of the material used) and "mass forces" (mainly gravitation). In the laboratory those forces which Wegener designated as "molecular forces" for convenience are relatively enormous. The tensile strength of the materials used plays a large rôle and so does the surface tension of the mixture of Plaster of Paris and water. The mass force of gravitation does not count at all or appears only as a disturbing factor. In

the actual events under consideration the mass force of gravitation overshadows all others by far; in such occurrences even the highest conceivable tensile strength of the toughest material is of no importance whatever.

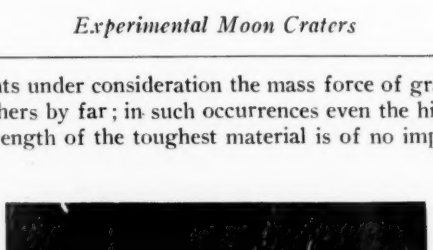

FIGURE 2

Another impact crater, diameter about 8 cm.

If an astronomical event, such as the impact of a large meteorite, is to be duplicated in the laboratory much care has to be exercised to select a material of negligible tensile strength. Only with such a material can one hope to achieve results which might stand comparison with actuality where the existing tensile strength of rock or metal becomes meaningless simply because of the scale of magnitude of the whole.

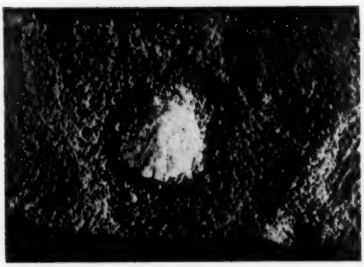

FIGURE 3

Another 8 cm crater, this time the powdered matter was Plaster of Paris to show its distribution. The "meteorite" spattered considerably across the crater rim, particles could be found as far as one meter from the center of the crater.

Consequently Dr. Wegener used cement powder for his experiments for both "meteorite" and "lunar surface." A fine powder, he reasoned, was likely to behave on a small scale and with low velocities in the same manner as rocks would behave on a very large scale and high velocities. He emphasized that he did not want to suggest that the lunar surface might consist of rock dust to any appreciable extent or depth, but that

the choice of powder was dictated only by the necessity of avoiding the disturbing appearance of molecular forces. "The powder of the experiments is simply the equivalent of solid rocks of actuality."

The experiments are easy to repeat, the whole equipment consists of a shallow tray which is filled with cement powder (or Plaster of Paris or even flour or anything of similar nature) and some extra powder which is dropped on this surface from the height of a few feet. Slanting illumination makes it easier to recognize the forms of the resulting roughly circular depressions and makes them easy to photograph. Cement powder has the advantage that it can be solidified without any disfiguration by means of repeated and careful application of a fine spray of water, followed by immersion of the whole model after several sprayings. (The accompanying photographs were taken before solidifying the models.)

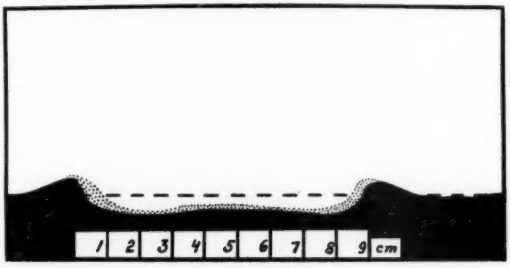

FIGURE 4

Cross sectional drawing of another and slightly larger "crater" produced by Plaster of Paris, showing the distribution of the "meteorite" (dotted). The broken line indicates the level of the cement surface before impact.

As can easily be seen the similarity between these models and the telescopic appearance of lunar craters is extraordinary. Nor is this similarity restricted to a few out of many experiments but can be counted upon in virtually every case.

The average diameter of the models is 10 cm, occasionally especially large craters of 12 cm or even 14 cm are obtained, while smaller models may be easily obtained simply by decreasing the size of the "meteorite." The interesting point is that the ratio between diameter and depth varies but little with the size of the model. For models of about 5 cm diameter that ratio is about 6, for models of 8 cm diameter it is about 7, for larger models around 10. The same ratio for actual lunar craters is between 7 and 10 in a few cases, the most frequently found value is 17. Other ratios yielded similar approximations between models and actual craters.

The most frequently asked question was, of course, what happens to

the "meteorite." This question could easily be answered by using powder of a different color for the dropped mass. Figure 4 shows such an experiment where Plaster of Paris was used for the "meteorite" while the ground consisted of cement powder as usual. The whole crater shows white. A cross section showed that the mass of the "meteorite" had spread thinly over the whole surface. It was somewhat thicker around the rim (on the inside) while particles had been thrown out over the rim for a considerable distance, up to 12 times the diameter of the crater.

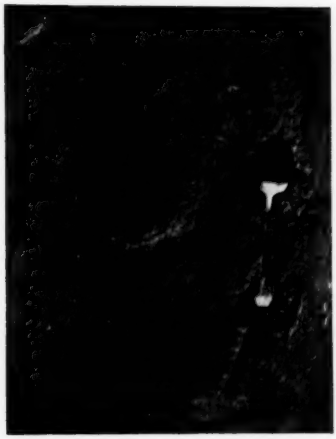

FIGURE 5

"Crater" on a cement layer about 1.5 cm thick, showing formation of a "central mountain." The soup spoon used is placed next to the model.

This corresponds well with the actual observations on Meteor Crater in Arizona and is possibly an answer to the still doubtful question of the position of the so-called "main mass." If these experiments can be applied to actual conditions all the way through—which is, of course, by no means an established fact even though it seems likely—there would be no "main mass" since the meteorite is always likely to break up into comparatively small fragments. It is to be hoped that exploration of the ground below Meteor Crater will be continued after the war to solve the "main mass question."

At first none of Dr. Wegener's experiments yielded a central mountain, until one was formed accidentally. Finding the conditions of this accidental formation it was easy later on to produce as many models with central cones as desired. A central mountain always formed when the thickness of the powder layer was less than 10 per cent of the diameter of the crater. Experiments with powder of a different color

and cross sectioning established the fact that the central mountain is in all cases ground material which was not carried outward to form the rim.

If this observation can be applied to large scale happenings it would mean that a central mountain is formed where a large and solid layer of very dense material can be encountered at a low depth below the surface. This does not seem to be the case in Arizona, consequently that crater is without a central mountain.

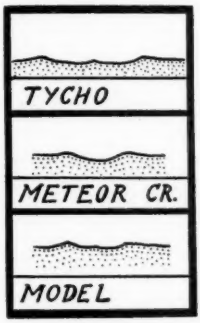

FIGURE 6

Cross sections according to Dr. Wegener, showing lunar crater Tycho, Meteor Crater in Arizona, and one experimental model. While the craters have been brought to about the same diameter for purposes of comparison their relative dimensions have not been changed.

It is not the purpose of this article to explore all the ramifications of Dr. Wegener's experiments, especially since they can be found in print even though not in English. But it does seem to the writer that these experiments are unduly neglected in discussions of the origin of meteoric craters and that continued experiments might well furnish additional clues. Of course it cannot be expected that experiments take *all* possible factors in account (for all terrestrial meteor craters the explosion of moisture in the ground under the heat of impact will be an important contributing factor) but these experiments have already yielded closer approximations to actual ratios of dimensions than any other ever made.

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Recurrence of Floods and Droughts after Intervals of about 90.4 Years

By E. L. MOSELEY

A year ago when POPULAR ASTRONOMY published my article "Solar Influence on Variations in Rainfall in the Interior of the United States," I was uncertain whether a precipitation cycle equal to four times the magnetic sunspot cycle applied farther west than Indiana. I am now convinced that it does apply to Iowa, Missouri, Arkansas, northern Louisiana, and eastern Oklahoma and Kansas. It seems probable that it applies also in Illinois and some other states from which as yet we have no data that go back ninety years.

Devastating floods in the spring of 1943 that wrought havoc in eight states from Indiana to Oklahoma followed by 90.4 years excessive precipitation in the same region. As time goes on, each new year makes available for comparison one or more places in this area whose record started more than ninety years before. There are now enough of these old records to furnish several examples of marked departure from normal during three or more consecutive months. By comparing these with recent records, we can find out whether similar departures usually come again after an interval of about 90.4 years.

Floods in the spring of 1943 are still vivid in the minds of those who were living in the flooded area. Let us first see what records show the amount of rain that fell in the same area 90.4 years earlier; that is, in the last part of the year 1852.

The oldest record in Indiana is that of Richmond; it began with 1852 and shows in December of that year a precipitation of 11.45 inches, nearly four times the usual amount.

In the last three months of 1852 heavy rain fell also at St. Louis and at several places in eastern Iowa. Fort Madison had 14.50 and Muscatine 18.47 inches, their average for that period being less than seven inches.

In October and November, 1852, Fort Scott, Kansas, and Fort Gibson, Oklahoma, had about double their usual amount of rain. Hope, Arkansas, had 7.70 inches in November alone.

The preceding statements suffice to show that throughout much of the area where floods were serious in the spring of 1943 rainfall was also very heavy 90.4 years before. Farther up the Ohio River than the southwestern part of Ohio, the flood at that time was less serious, likewise the surplus of rain in the last months of 1852 was less.

Iowa has enough records antedating 1852 to make possible the comparison of several early periods of copious rain, and others of deficient rain, with periods 90.4 years later.

In May, June, and July, 1851, 35.50 inches of rain fell at Muscatine,

Iowa; this is nearly three times the average for those three months. In the same period Farmersburg, Iowa, had ten inches of rain in excess of its average, and Dubuque and Fort Madison more than twice their average.

These are the only places in Iowa whose record of rainfall includes the year 1851, but for 1941 we have a record for 120 places in that state. Everyone of them shows excessive rain in October and nearly every one in September. For those two months it was the greatest precipitation in the entire record. In the southeastern part of the state more than three and a half times the usual amount of rain fell in October. In November precipitation for the state was a little above and in December it was more than sixty per cent above normal. These four wet months in 1941 followed by about 90.4 years the months of excessive rain in 1851.

In neighboring states we find that Peoria had 10.52 inches of rain in October, 1941, the greatest for that month in its entire record of 87 years, the longest weather record in the state of Illinois. At St. Louis the rainfall in October, 1941, has been exceeded only three times in October in a record of 106 years. It had 20.93 inches of rain in June, July, and August, 1851. At Miami, the only other place in Missouri with a record old enough to be compared with that of 90.4 years later, 28.92 inches of rain fell May-August, 1851.

Rain was excessive in Iowa in the summer of 1850, at the only places for which there is a record, Farmersburg, Fort Madison, and Muscatine. After an interval of 90.4 years it was excessive throughout the state.

Two places in Iowa, Decorah and Farmersburg, both in the northeastern part of the state, have records for 1844. They show excessive rainfall in July and August of that year. The whole state had excessive rain 90.4 years later; in November, 1934, it received more than three times the usual amount.

In the last three months of 1845 and the first two months of 1846 precipitation at Decorah and Farmersburg was unusually light. Most residents of Iowa can recall the drought in 1936. From March to August, 90.4 years after the dry period in 1845-46, very little rain fell in that state.

From these examples it appears that in the state of Iowa marked departures from normal precipitation during two or more consecutive months, as shown by early records at two or more places, have been followed after 90.4 years by departures in the same direction. An exception is the record for three places in eastern Iowa, one of them interpolated, that shows excessive rain during many months of 1849. In the corresponding period 90.4 years later there was less rain than usual in both Iowa and Missouri. However, at St. Louis, 1849 had seven months with less rain than usual.

Leavenworth, Kansas, has a record that goes back to 1836. It shows

that the 90.4 year precipitation cycle applies in that region. In the year 1843 only 13.44 inches of rain fell there, all months except April showing a shortage. There was a similar lack of rain from September, 1933, to and including March, 1934. In 1844 rainfall was excessive from May to July and in 1934 from September to November. Very little rain fell at Leavenworth during the last three months of 1845 and the first three of 1846, likewise in 1936 from February to August, excepting April and May.

However, it is not safe to base predictions on the early weather records at a single locality. Nothing in the record at Leavenworth would have warranted predicting the recent heavy rains in that region. Fort Scott, Kansas, did have more than twice the usual amount of rain in October and November, 1852, which was 90.4 years prior to the spring of 1943. It had very heavy rain in 1844 when rain was excessive at Leavenworth, the rainfall in the four months, April to July, totalling 44.84 inches. Also like Leavenworth, it had little rain in the last part of 1845 and the first part of 1846. When the two places agree, there is more probability that a forecast based on the early records will come true. It is unfortunate that Kansas does not have more of these early records of precipitation.

In Oklahoma the only places with precipitation records old enough for our purpose are Fort Gibson and Fort Towson, both in the eastern part of the state. In Arkansas the only old record is at Hope, in the southwestern part of the state, less than one hundred miles east of Fort Towson. We have said that this area had copious rain 90.4 years before the great flood of 1943. It had a drought in the last six months of 1845 and the first month of 1846, that is, 90.4 years before the drought in the first half of 1936. In the first part of 1840 there was heavy rain in this region, also in May, 1930. Fort Towson and Hope had surplus rain in January and February, 1850, and from May to July, 1940.

In 1851 very heavy rain fell in February at each of the three places; likewise there was a marked surplus in June and July, 1941. In 1852 the Fort Towson record is missing but the two other stations show that this region had excessive rain in the period May-August. There was a surplus in the same region in 1942, September to December.

Very few exceptions to the rule were found for this area.

We now have evidence that the 90.4 years precipitation cycle applies to much of the region extending from eastern Kansas and Oklahoma to eastern New York and Pennsylvania. In time we may find out how far north and south it extends.

The author still has reprints of some of his earlier papers relating to this cycle.

Outlook for the Future

Forecasts based on the 90.4 years precipitation cycle for different parts of the area extending from Kentucky and Indiana to western

New England were published in *Country Gentleman*, November, 1943, pages 12, 38, and 40. Because of the paucity of records earlier than 1856, we cannot so confidently predict the character of the rainfall to be expected in Illinois or in any of the states west of the Mississippi River, for the years 1944 and 1945.

The last quarter of 1853 and the first third of 1854 were dry in most of the area west of the Mississippi with which we have been dealing, so it seems probable that it will be dry in the growing season of 1944. In 1945 it will probably be dry again during most of the growing season in much of Iowa, in the northern half of Missouri, and in the eastern part of Kansas and Oklahoma. In western Arkansas the summer of 1945 will probably be dry. In most of these states the winter of 1944-45 is expected to be dry.

The drought which is expected to affect many of the states east of the Mississippi in the latter half of 1946 and during much of 1947 will probably not affect seriously the states from Illinois west. Some of them will probably get more than the usual amount of rain in 1947 and little if any less than usual in the latter half of 1946.

For the year 1858 we have records of precipitation at seven places in Illinois and seven in Iowa, three in eastern Nebraska and two in eastern Kansas. An unusual amount of rain fell in all these states in the period April-July. Hence the late summer and all of the fall of 1948 will probably be wet.

After August, 1858, there was again more rain than usual in the same area, and in 1859 from March to June, so that wet weather may be expected in the summer and fall of 1949. Probably in most places enough rain will fall also in the spring of 1949.

During the last half of 1859 there was a shortage of rain in most of this region, so that the winter, 1949-50, and the spring of 1950 will probably be dry.

At St. Louis the year 1860 was the driest between 1837 and 1870. At Miami in the same state only 15.73 inches of rain fell in 1860, the driest in its entire record. At Oregon, Missouri, only two of the twelve months afforded as much rain as usual. At Leavenworth, Kansas, 1860 was the driest year in its long record, except 1843 and 1864. Hence, in the northern half of Missouri and in northeastern Kansas very dry weather may be expected for early in the summer of 1950, continuing for about a year.

Likewise, there was a shortage of rain in 1860 at each of the six places in Iowa and the three in Illinois whose record includes that year, but at most of these places the shortage was less than in Missouri.

University Museum, Bowling Green, Ohio.

A Statistical Study based upon Four Methods for Computing Meteor Heights

By EDITH FRANCES REILLY

In this study I computed the heights of 20 meteors by four methods, namely, by Schaeberle's two methods, by the graphical method, and by Whitney's method. Schaeberle[1] gives two methods of computing the distance from the observer to the point at which the meteor was first seen and also to that at which it disappeared. The method labeled "short" (hereafter denoted as A) is the better method when the difference in right ascension is greater than that in declination; that labeled "long" (hereafter denoted as B) is the better when the difference in declination is the greater. Of the 20 meteors studied, only three thus *required* B, namely Nos. 17, 18, 20, although it was used for all. The graphical method[2] (hereafter denoted as C) is one often used at the Headquarters of the American Meteor Society, Flower Observatory, University of Pennsylvania. Whitney's method[3] (hereafter denoted as W), devised while he was at Flower Observatory, minimizes the errors of observation by adjusting the observed directions of the meteor from two stations through two equal angles, γ_1 and γ_2.

The first column in each of the tables gives the serial number of each meteor. In Table I are tabulated the dates, times, coördinates of the stations, S_1 being west of S_2, distance between the stations expressed in kilometers, observers, and the heights computed by the several methods. Table II shows the correlations found from these methods. The second, third, and fourth columns show the results of applying the great circle test used by Schaeberle:

$$\tan D_2 \sin (\alpha_2 - \alpha_1) - \tan \delta_1 \sin (\alpha_2 - A_2) + \tan \delta_2 \sin (\alpha_1 - A_2) = 0. \quad (1)$$

The results are expressed in units of the third decimal. In the second column is tabulated the sum of the positive terms, in the third the negative terms and in the fourth the total value of the left side of the equation, under the heading ΔG. The next four columns give ΔZ of method A and ΔX, ΔY, and ΔZ of method B. While it has long been known that ΔX and ΔY are actually equal to zero for method A, why this is true seems not to have been clearly pointed out. It is because R, ϕ', θ, A_2, and D_2 are, at any given moment, constants. The observed coördinates of the meteor, however, appear in ΔZ, and good internal agreement

[1] *Contributions of the Lick Observatory* No. 5, and Charles P. Olivier "Meteors."

[2] *Flower Observatory, Reprint No. 11*, and Hydrographic Office, U.S.N., Supplement to the Pilot Chart of the North Atlantic Ocean for 1931.

[3] *Flower Observatory, Reprint No. 35. Monthly Notices, R.A.S.*, Vol. 96, No. 5, 1936.

of the two observations is indicated by a small ΔZ. Hence there must be a close correlation between ΔG and ΔZ. ΔG is given by equation (1) and ΔZ is given by:

$$\Delta Z = R_1 \sin \phi_1' - R_2 \sin \phi_2' \{K \cos D_2 / \sin (\alpha_2 - \alpha_1)\} \{\sin (\alpha_1 - A_2) \tan \delta_1 - \sin (\alpha_1 - A_2) \tan \delta_2\}. \quad (2)$$

The following correlations were found:

1. When A is required, 17 cases, the heights at beginning (hereafter denoted as H_b) of meteors Nos. 9, 10, 14, and 19 and the end heights (H_e) of meteors Nos. 10 and 19 do not agree with W. The results are said to "agree" if they differ by 5 km or less.

2. When B is required, three cases, the H_b of meteor No. 17 is the only one which does not agree with W.

3. Method C does not yield a good agreement with W. The H_b of meteors Nos. 2, 3, 5, 9, 11, 13, 15, 16, and 20 and the H_e of Nos. 1, 3, 4, 7, 9, 11, 15, and 20 do not agree with W.

4. When the correct choice of A or B is made, a greater ΔZ accompanies a greater ΔG for every meteor except No. 15. This is to be expected, because, as pointed out above, ΔZ and ΔG are similar functions of the same quantities.

5. When A is used, whether required or not, in each case except the beginning for meteor No. 16 and the end for No. 7, ΔZ has the sign opposite to that of ΔG.

6. When the beginning and end points are considered in B, ΔX, ΔY, and ΔZ disregarding sign, increase or decrease with ΔG, in the majority of cases. This was found to be true in 17 cases for ΔX, in 12 cases for ΔY and in 15 cases for ΔZ. In the three cases requiring B it was found to be true.

7. When the heights found by using the more appropriate Schaeberle method, A or B, were compared with those from W, the differences being considered without regard to sign, it was found that the smaller difference accompanied the smaller ΔG in 14 cases. In two cases, Nos. 15 and 19, the opposite was true. In four cases, Nos. 3, 4, 5, and 11, the differences were equal at beginning and end. For No. 3 the smaller ΔG was at the end and in the other three cases at the beginning.

8. When C was compared with W and the ΔG, the smaller difference accompanies the smaller ΔG for meteors Nos. 1, 2, 3, 4, 7, 8, 9, 12, 13, 14, 17, and 20. The opposite was true for Nos. 5, 6, 15, 16, 18, and 19. For Nos. 10 and 11 the differences, beginning and end, were equal, No. 10 giving the smaller ΔG at the end.

9. Still considering only the appropriate method of Schaeberle, it was found that H_e for meteors Nos. 3, 8, 9, 10, 14, and 19 have a large deviation from the mean, *i.e.*, 5 km or more. Of these Nos. 9, 10, 14, and 19 did not agree well with W, but the ending agreed better than

TABLE I

No.	Date	E.S.T. h m s	λ ° ′ φ ° ′	Dis. (km)	Obs.	Schaeberle Beginning Short	Schaeberle Beginning Long	Schaeberle End Short	Schaeberle End Long	Graphical Beginning	Graphical End	Whitney Beg.	Whitney End
1	Nov. 13/14, 1923	13:05:01	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	111.40 ± 1.14	128.02 ±14.52	140.74 ± 0.77	135.42 ± 0.04	108.87 ± 1.69	133.30 ± 1.75	112.36	139.03
2	Nov. 13/14, 1923	14:00:04	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	138.92 ± 3.08	138.44 ±11.15	81.06 ± 1.34	68.45 ±14.82	121.43 ±10.85	81.38 ± 2.20	134.87	82.97
3	Nov. 13/14, 1923	14:20:12	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	108.95 ± 8.32	109.02 ±31.65	45.34 ± 7.20	48.21 ± 6.76	71.24 ±41.90	57.02 ±20.11	107.82	46.04
4	Nov. 13/14, 1923	15:09:57	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	116.79 ± 0.29	130.25 ±15.40	87.43 ± 0.57	113.60 ±28.40	115.10 ± 4.82	80.39 ± 5.31	116.06	88.45
5	Dec. 10/11, 1923	13:05:50	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	94.29 ± 1.50	96.70 ± 1.11	73.57 ± 2.45	76.69 ± 1.69	88.51 ±27.93	74.52	95.59	75.89
6	Dec. 10/11, 1923	13:41:16	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	101.30 ± 0.54	97.39 ± 2.86	89.88 ± 0.55	89.27 ± 0.51	99.29 ± 0.09	84.60 ± 5.25	101.51	89.97
7	Dec. 10/11, 1923	14:24:36	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	99.68 ± 1.59	95.92 ± 6.06	73.95 ± 5.96	84.63	100.40 ± 9.93	86.01 ±38.67	100.51	76.58
8	Dec. 10/11, 1923	14:43:02	{ 78 31 39 2 / 77 4 38 55 }	158.30	A O1	116.29 ± 5.39	122.47 ±16.62	89.21 ± 0.00	91.51 ± 3.38	113.65 ±19.95	88.10 ± 1.81	111.46	89.33
9	Dec. 10/11, 1923	15:33:12	{ 78 31 38 2 / 77 4 38 55 }	158.30	A O1	75.51 ± 5.10	101.23 ±41.99	64.19 ± 2.20	61.96 ± 5.06	93.49 ±42.94	83.28 ±30.75	69.06	61.02
10	Nov. 15/16, 1933	13:38:33	{ 76 58 39 21 / 75 13 40 5 }	169.02	F O1	129.40 ± 9.05	99.23 ± 0.95	90.01 ± 6.35	119.05 ±48.13	121.49 ±26.73	79.36 ±77.14	118.55	81.49
11	Nov. 15/16, 1933	14:25:46	{ 76 58 39 21 / 74 20 39 26 }	223.47	W E	127.03 ± 1.14	129.04 ± 0.98	97.75 ± 8.42	104.43 ± 0.98	120.52	91.54	127.29	97.50

TABLE I (Continued)

TABLE I (CONTINUED)

No.	Date	E.S.T. h m s	λ, φ,	Dis. (km)	Obs.	Schaeberle Beginning Short	Schaeberle Beginning Long	Schaeberle End Short	Schaeberle End Long	Graphical Beginning	Graphical End	Whitney Beg.	Whitney End
12	Nov. 15/16, 1933	15:25:07	77 25 39 25 75 13 40 5	200.52	M O1	125.18 ± 1.47	126.42 ± 8.57	93.00 ± 0.54	69.82 ±22.65	119.83 ± 5.60	90.95 ± 1.18	124.34	93.24
13	Nov. 15/16, 1933	15:42:10	77 25 39 25 74 20 39 26	262.06	M E	106.94 ± 4.52	95.91 ±22.83	94.06 ± 0.39	94.86 ± 0.29	98.17 ±12.57	91.79 ± 1.30	105.54	93.80
14	Nov. 16/17, 1933	12:45:30	77 25 39 25 75 17 39 58	191.10	M O1	147.63 ±13.66	84.08 ±11.38	63.26 ± 0.76	60.29 ± 0.16	125.04 ±22.56	59.54 ± 1.70	128.74	62.23
15	Nov. 16/17, 1933	13:15:10	77 25 39 25 75 17 39 58	191.10	M O1	120.04 ± 2.25	119.48 ±10.88	94.98 ± 1.94	92.53 ± 9.12	102.91 ± 9.16	87.51 ± 6.14	115.88	93.67
16	Nov. 16/17, 1933	13:46:13	76 58 39 21 75 17 39 58	158.42	W O1	95.59 ± 0.31	95.04 ± 1.70	100.47 ± 3.67	110.96 ±14.35	87.88 ± 7.18	105.62 ±11.41	95.59	101.77
17	Oct. 25/26, 1941	12:35:50	75 14 40 4 75 12 40 35	56.17	H V	81.63 ± 6.37	128.26 ± 1.82	89.81 ± 5.71	68.11 ± 0.44	106.31 ± 9.23	73.02 ± 4.84	108.92	71.29
18	Oct. 25/26, 1941	13:00:54	75 14 40 4 75 12 40 35	56.17	R Mg	148.48 ± 0.59	153.75 ± 0.39	99.73 ± 6.24	62.85 ± 2.58	149.16 ± 0.08	69.84 ± 4.27	153.18	68.17
19	Nov. 15/16, 1941	14:40:25	75 44 40 3 75 9 40 7	49.96	C O1	103.68 ± 5.16	*31.31 ± 7.20	73.52 ±10.58	*14.48 ± 4.78	94.97 ±10.16	68.76 ±11.30	91.12	65.75
20	Nov. 15/16, 1941	14:50:34	75 44 40 3 75 9 40 7	49.96	MR O1	134.93 ± 3.20	112.97 ± 1.69	*190.37 ± 9.85	106.05 ± 4.13	101.90 ± 2.50	80.38 ± 6.92	115.88	110.05
					Mean	114.18	113.87	86.42	87.30	107.00	83.34	111.71	84.41

*Omitted from means.

A—H. L. Alien, O1—C. P. Olivier, F—J. B. Field, W—P. S. Watson, E—J. W. Evans, M—F. F. Marsh, H—W. H. Haas, V—J. Vrable, R—E. F. Reilly, Mg—J. Metzger, C—J. Connor, MR—D. MacRae.

the beginning. Numbers 3, 8, 9, 10, and 14 have ΔG and ΔZ larger at the beginning than at the end.

Nos. 3, 7, 10, 11, and 19 have a large deviation from the mean in H_b. Of these only 10 and 19 do not agree with W. For Nos. 7 and 11 the ΔG and ΔZ are larger at the end, but the beginning for No. 7 agrees better with W and for No. 11 the differences were equal at the beginning and end. When there is a large deviation from the mean at both points as in Nos. 3, 10, and 19 the point that has the larger deviation also has the larger ΔG and ΔZ. When compared with W, No. 10 only gives a poorer agreement for the point at which the other three correlations are poorer. For No. 3 H_b and H_e agree equally well with W, while in No. 19 the poorer agreement is at the point at which the agreement is the better in the other correlations.

10. Every H_b in C which has a poor agreement with W, with the exception of Nos. 11 and 20, also has a large deviation from the mean. In H_e, Nos. 1 and 11 were the only exceptions to this correlation. The altitude method was applied to meteor 11 which was exceptional in both H_b and H_e.

11. By correlating the agreement of the appropriate Schaeberle method and C with W, the deviation from the mean and ΔG, I tried to find the limit for ΔG which would give a good agreement with W and a small deviation from the mean. The results follow:

(a) Schaeberle's appropriate method, A or B.

(1) for H_b ΔG from 0 to 56,—thirteen meteors, Nos. 1, 2, 4, 5, 6, 7, 11, 12, 13, 15, 16, 18, and 20.

(2) for H_e ΔG from 0 to 112,—eighteen meteors,—all except Nos. 10 and 19.

(b) For C.

(1) for H_b ΔG from 0 to 24,—seven meteors,—Nos. 1, 4, 6, 11, 12, 16, and 18.

(2) for H_e ΔG from 0 to 30,—nine meteors,—Nos. 1, 2, 4, 6, 8, 12, 13, 14, and 15.

12. Using the meteors listed in 11 (a), the deviations from W and the deviations from the mean were found. The greatest deviation from W in H_b was 4 and the greatest deviation from the mean 4.52. For H_e these values were 5 and 8.42, respectively. Treating 11 (b) in the same manner, the values found for H_b were 8 and 7.18, and for H_e, 8 and 6.14.

All of the meteors of 11 (a) H_b except Nos. 2 and 13 have γ of Whitney's method less than 1°. For No. 2 the ΔG was the greatest, 56, γ was 1°.4, the deviation from W the greatest, namely 4, and the deviation from the mean 3.08. For No. 13 ΔG was 55, γ was 2°.2, the deviation from W 1, and that from the mean 4.52. The greatest γ for the 18 meteors of 11 (a) H_e was 4°.1. For the meteors of 11 (b) for both

H_b and H_e the greatest γ was 0°.7 and 1°.1, respectively. Of those with γ greater than 1° for beginning points, only Nos. 2 and 13 fell in class 11 (a). Only No. 19 is missing from 11 (a) H_e and this had $\gamma = 5°.0$. For the graphical method, 11 (b) when γ was greater than 1°, if there was any good agreement it was generally with W.

13. By comparing the results of A and B with W, station by station, it was found that for 13 meteors for H_b the better agreement was not for the same station. This happens in H_e for only 5 meteors, four of them being those which have this correlation in H_b. When Schaeberle's appropriate method is thus compared with C, this shift is found in 8 meteors in H_b and in 7 in H_e, of which only 3 correspond to the same correlation in H_b.

TABLE II

			Short		Long		
No.	G+	G—	ΔG	ΔZ	ΔX	ΔY	ΔZ
1 B	387	402	— 15	47	84	— 687	0
1 E	381	363	18	— 59	— 86	25	— 7
2 B	639	583	56	— 177	— 334	409	97
2 E	491	514	— 23	70	383	— 569	— 119
3 B	948	1129	— 181	402	592	— 810	— 642
3 E	830	737	93	— 218	— 170	106	201
4 B	597	586	11	— 34	— 273	476	109
4 E	623	603	20	— 49	— 333	966	146
5 B	575	603	— 28	62	43	— 49	— 9
5 E	486	546	— 60	112	56	— 83	6
6 B	848	855	— 7	13	— 107	— 16	118
6 E	808	814	— 6	11	10	— 25	— 10
7 B	697	723	— 26	59	67	— 210	— 47
7 E	632	543	89	280	281	—2744	— 423
8 B	1029	898	131	— 290	— 141	482	205
8 E	790	774	16	— 37	— 8	97	35
9 B	633	516	117	— 274	— 311	2392	— 512
9 E	555	502	53	— 124	— 86	235	— 58
10 B	495	339	158	— 463	— 536	196	— 65
10 E	494	372	122	— 326	46	—1248	— 907
11 B	388	374	14	— 52	58	3	— 53
11 E	315	203	112	— 413	194	264	— 268
12 B	396	372	24	— 78	— 162	276	35
12 E	327	323	4	— 30	— 376	1019	— 47
13 B	27	82	— 55	228	— 270	642	283
13 E	111	108	3	— 14	37	13	— 13
14 B	296	151	145	— 698	—1176	61	— 74
14 E	210	197	13	— 52	— 154	79	— 29
15 B	296	269	27	— 119	— 487	500	102
15 E	286	256	30	— 107	— 375	444	43
16 B	617	619	— 2	— 22	— 50	48	27
16 E	433	500	— 67	172	519	— 515	— 174
17 B	432	581	— 149	306	201	— 42	— 55
17 E	505	393	112	— 283	— 70	17	18
18 B	177	180	— 3	20	13	7	— 1
18 E	302	245	57	— 321	— 140	— 34	6
19 B	156	39	117	— 257	— 640	251	— 11
19 E	209	46	163	— 307	— 723	151	— 13
20 B	401	427	— 26	156	25	— 49	— 18
20 E	300	348	— 48	475	57	— 140	— 28

14. Where A is the appropriate method, this method gives the best

agreement with W in H_b and H_e of all the methods here considered. As only three meteors had B as the appropriate method, there was insufficient material for a similar comparison.

It should be added that not all of the persons who made the observations were trained meteor observers. Some had very little experience. Therefore it cannot be expected that all the data were highly accurate. A similar study based wholly upon the observations of two very experienced observers would be most instructive.

FLOWER OBSERVATORY OF THE UNIVERSITY OF PENNSYLVANIA, UPPER DARBY, PENNSYLVANIA.

The Planets in July and August, 1944

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern War Time, subtract 4 hours; Central War Time, 5 hours, etc. The information is taken from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will move from the constellation Gemini, through Cancer, and into Leo. On August 31 it will be a very short distance east of Regulus, this bright star necessarily being invisible at this time. It will move eastward from $6^h\,39^m$ to $10^h\,37^m$, and southward from $+23°\,8'$ to $+8°\,47'$.

On July 20 there will be an annular eclipse of the sun. Because of the inaccessibility of its path, this eclipse will not attract much attention. Details concerning it are given on pages 31 and 32 of the January issue.

Moon. The phases of the moon will occur as follows:

	d	h
Full Moon	July 6	4
Last Quarter	12	21
New Moon	20	6
First Quarter	28	9
Full Moon	August 4	13
Last Quarter	11	3
New Moon	18	20
First Quarter	27	0

It will be in perigee on July 8 and again on August 5; in apogee on July 24 and again on August 21.

Mercury. On July 1, Mercury will be in conjunction with the sun in right ascension and less than two degrees north of the sun in declination. Its rapid motion eastward will bring it to a position of greatest eastern elongation on August 10. On this same date it will be at a point of greatest distance from the sun in miles. After this date its angular distance from the sun will lessen and soon it will again be invisible in the twilight. It will be south of the equator for the interval from August 21 to September 1. Mercury will remain east of the sun until the end of this period.

Venus, having been at superior conjunction on June 27, will be only a few minutes east of the sun on July 1. Its motion eastward will be a little more rapid than that of the sun so that by the end of August it will be one hour and seven minutes east of the sun. It will therefore not become conspicuously present in the evening sky, but may be seen there if looked for during the latter half

of August. Venus will be at perihelion, nearest the sun in linear units, on July 19. This item, however, has small significance in the casual observation of the planet.

Earth. The earth will be in aphelion, farthest from the sun, on July 3, a source of surprise to many persons, especially those living in the northern hemisphere who normally experience summer heat at that time, the simplest explanation for which would seem to be that the earth is then closer to the sun than usual.

Mars. Mars will continue to move eastward ahead of the sun, although more slowly than the sun. This planet will still be visible just after sunset in July. In August it will disappear in the twilight.

Jupiter. At the beginning of this period Jupiter will still be slightly more than three hours east of the sun. Its motion eastward during the two months will be such that the sun will overtake it on the last day of the period, August 31. Therefore, like Mars, Jupiter will be visible during the first part of July but practically invisible for the rest of July and during August.

Saturn. Saturn, having been passed by the sun on June 21, will continue to lag behind the sun as both objects move eastward. The effect of this will be to cause Saturn to rise earlier in the morning from day to day. By the middle of August it will rise long enough before sunrise to be visible as a morning star.

Uranus. Uranus, like Saturn, if observed at all, must be observed in the early morning. It will be in the constellation Taurus, a short distance east of the Pleiades. On August 1 Uranus will cross the meridian at about eight A.M.

Neptune. Neptune will be in the constellation Virgo during July and August. It will, therefore, be in the evening sky well above the horizon at sunset during July. Its position on August 1 will be $12^h\ 10^m$, $+0°\ 26'$.

Asteroid Notes

By HUGH S. RICE

Asteroids do not of course arrange themselves for the convenience of the observer. At times, all of the Big Four (Ceres, Pallas, Juno, and Vesta) are in good position for observation with small instruments; at other times none of them is visible. Such occurrences are somewhat rare however, the commoner situation being that some of the bright ones are in favorable places, and the others invisible. Along with the Big Four there are usually a few of the asteroids to be seen, which are the brightest of the remaining host of thousands of them but which are less commonly known. In descending order of magnitude, some of these are: 7 Iris, 6 Hebe, 15 Eunomia, 9 Metis, 8 Flora, 29 Amphitrite, 20 Massalia, 40 Harmonia, 11 Parthenope, 18 Melpomene, and 192 Nausikaa. Even with this list we have only recorded those of magnitude 9.3 or brighter, there being several others brighter than magnitude 10.0.

It is a huge undertaking to keep a good check on the 1513 or more asteroids whose orbits are well known, by making, reducing, and recording observations, checking and revising the orbital elements, computing and publishing ephemerides for opposition times, as well as issuing bulletins that go to interested observers all over the world. Normally this work has been carried on at the Copernicus-

Institut near Berlin. The only important asteroid computations in the United States at present, of which we are aware, are those made by the Yale Observatory.

This summer happens to be one of the unusual times when no bright minor planets at all are available for observation. They will begin to be visible in the latter half of the year, and we shall have a rather rapid succession of apparitions of the following planets: 3 Juno, 7 Iris, 2 Pallas, 4 Vesta, 1 Ceres, 27 Euterpe, and 6 Hebe. For example, in October Vesta will be south of the triangle in Leo, and a little fainter than magnitude 8. We expect therefore to have plenty of asteroids to observe during the autumn and winter months.

Hayden Planetarium, American Museum of Natural History, New York, New York, May 28, 1944.

Occultation Predictions for July and August, 1944

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

				IMMERSION				EMERSION			
Date 1944	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N		Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°		h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′											
July 2	49 Libr	5.5	23 15.0	−2.3	+3.0	58		23 56.1	0.0	−2.1	350
4	81 B.Ophi	6.3	0 7.1	−2.0	+2.5	59		0 54.4	−0.4	−1.3	339
8	30 Capr	5.4	9 44.2	−0.6	+0.4	38		10 40.3	−1.1	−1.6	281
11	30 Pisc	4.7	5 3.5	..	..	141		5 20.9	..	..	174
30	η Libr	5.6	2 41.2	..	..	44		3 19.0	..	..	347
Aug. 6	74 Aqar	5.9	9 31.7	−1.3	−1.2	94		10 27.4	−0.3	+0.5	214
10	ξ^2 Ceti	4.3	5 35.3	−0.3	+2.2	41		6 34.4	−1.0	+1.2	268
12	63 Taur	5.7	9 38.7	−2.0	+0.5	104		10 43.5	−1.1	+2.6	214
16	85 Gemi	5.4	7 55.7	−0.1	−0.2	141		8 29.5	+0.8	+2.6	217
27	109 B.Ophi	6.2	22 56.6	..	..	172		23 30.8	..	..	220
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′											
July 3	81 B.Ophi	6.3	23 41.1	−0.6	+1.2	94		0 44.0	−0.6	+0.2	304
8	30 Capr	5.4	9 31.2	−0.4	+2.0	14		10 13.2	−2.6	−2.5	305
30	η Libr	5.6	1 58.0	−2.6	+0.4	67		3 1.4	−1.4	−2.5	334
Aug. 6	74 Aqar	5.9	9 5.0	−1.6	0.0	74		10 15.2	−1.0	+0.3	231
10	ξ^2 Ceti	4.3	5 29.0	+0.1	+2.2	33		6 16.7	−0.5	+1.0	281
11	8 B.Taur	6.2	6 36.7	−0.7	0.0	130		7 3.2	+0.6	+3.4	185
12	63 Taur	5.7	9 10.9	−0.9	+1.5	84		10 18.6	−0.9	+2.0	232
15	ξ Gemi	3.9	8 33.6	−0.6	−1.3	151		8 54.4	+1.3	+3.7	197
16	217 B.Gemi	6.3	10 18.4	..	..	158		10 39.6	..	..	200

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

				h	m	m	m	°	h	m	m	m	°
July	9	50	Aqar	5.9	13	5.9	..	..	355	13	33.1	..	..	311
	10	ψ^2	Aqar	5.2	10	38.4	−2.1	+0.8	83	11	52.2	−1.4	+1.5	220
	29	13	Libr	5.8	1	1.6	−2.2	+0.2	101	2	25.6	−1.6	−1.5	318
	30	η	Libr	5.6	0	54.2	−1.4	−0.1	120	2	17.3	−1.9	−0.3	293
Aug.	2	28	Sgtr	5.8	8	19.2	−2.3	−2.5	137	9	3.5	−0.4	+1.1	211
	6	74	Aqar	5.9	8	14.1	−1.5	+1.7	45	9	27.6	−2.1	+0.4	264
	12	63	Taur	5.7	8	56.6	+0.2	+1.6	63	9	53.6	−0.3	+1.3	259

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

					h	m	m	m	°	h	m	m	m	°
July	1	B.D.—9°3945		6.7	5	25.3	−1.5	−1.9	120	..	..	..	..	..
	3	81	B.Ophi	6.3	23	35.4	+0.1	−0.4	134	0	32.1	−1.0	+1.2	265
	8	30	Capr	5.4	9	6.2	−1.5	+1.7	33	10	12.6	−2.5	−1.1	283
	9	50	Aqar	5.9	13	9.1	−0.8	+0.1	60	14	12.3	−0.5	−0.3	249
	10	ψ^2	Aqar	4.6	11	17.0	−0.9	+2.2	22	12	19.7	−2.4	−0.9	276
	29	13	Libr	5.8	2	1.7	−3.1	0.0	79	3	14.1	−1.5	−2.9	333
	30	η	Libr	5.6	1	39.4	−2.6	−0.4	102	3	9.8	−2.1	−1.7	306
	31	BD—18°4302		7.1	2	28.6	−2.7	+0.1	89	..	..	..	..	..
	31	BD—18°4320		6.9	6	55.5	−0.8	−0.8	84	..	..	..	..	..
Aug.	6	74	Aqar	5.9	8	51.1	−2.5	−0.1	88	10	0.1	−1.0	+1.4	213
	10	ξ^2	Ceti	4.3	..	..	..	..	..	6	3.7	−0.1	+1.1	263
	12	63	Taur	5.7	8	54.0	−0.8	+0.7	99	9	50.6	−0.3	+2.5	216
	13	353	B.Taur	6.4	11	1.6	+0.5	+4.5	12	11	41.2	−3.1	−1.7	310
	15	120	B.Gemi	6.5	11	6.0	+0.6	+3.6	79	11	43.9	−1.8	−1.4	318
	28	BD—20°4661		7.4	1	51.3	−2.5	−0.6	101	..	..	..	..	..
	29	14	Sgtr	5.7	5	35.5	−0.5	+1.1	37	6	22.5	−1.6	−2.7	314
	30	BD—22°5021		6.9	5	11.3	−1.8	−0.3	79	..	..	..	..	..

*Computation by Tecla Combariati and J. Lynn Smith, communicated by Captain J. F. Hellweg, Superintendent U.S. Naval Observatory.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Last year, despite the demands of war which should of course have entire precedence, a good many persons managed to observe the Perseids. A brief résumé of their reports appeared in the Meteor Notes for December last. These Notes were separately reprinted and have been mailed to every observer who is not in the A.M.S. These latter will receive theirs in the regular annual reprint. I trust that this procedure will help to enlist the aid of all these non-member observers both for 1944 and for following years at the Perseid epoch. As to moonlight, in 1944 the conditions are only moderately favorable for the Moon is at last quarter on August 11, the usual night of maximum. It will be at midnight roughly 43° from the radiant and will obviously be above the horizon for the rest of the night. On succeeding nights, the earlier hours will be free of moonlight but meteors usually are not numerous until about two hours before true midnight. With clear skies and fairly good places for observations nevertheless large numbers of meteors should be seen on all the nights beginning with that of August 10/11 and ending with that of August 12/13.

A.M.S. members are urged to make a much better effort than in 1943 to plot what they observe. If they need maps, etc., requisitions should arrive here some weeks in advance, not the day before maximum when supplies cannot be mailed in time. I also urge that persons carry a field glass or even an opera glass

with them for observation of trains which last a few seconds to the unaided eye. Small optical help may enable them to observe and record the all-important train-drifts. Parallax work is, as usual, recommended when two observers can occupy simultaneously stations from 30 to 70 miles apart. Advice will be gladly given for such programs if letters arrive far enough in advance. We take this opportunity to cordially invite the aid of all persons, interested in any sort of science, in making hourly counts of meteors on any or all of the nights mentioned. Please mail such records to the writer.

The rest of these Notes consists of such results as could be derived from four fireballs for which two observations each were in our possession.

Fireball of 1936 March 25/26

On this date the following two reports were published in the *Hydrographic Bulletin*, U.S.N. S1 "Second Officer H. L. Perkins . . . Am. S. S., W. W. Burton . . . on March 26, 1936, in latitude 25° 05′ N, longitude 84° 15′ W, at 0754 G.M.T. a meteor . . . falling vertically from an altitude of 20°, bearing 185° . . . at 15°, it began to glow with a bright blue color, becoming more radiant as it neared the horizon and lighting up the surroundings with a dull glow. The body disappeared at the horizon, leaving no trail . . . visible about 5 seconds. Sky . . . clear." S2 "Second Officer R. A. Scott . . . Am. S. S., Eastern Sun . . . at 0853 G.M.T. in latitude 26° 17′ N, longitude 86° 54′ W, a very bright greenish white meteor about five times the size of Jupiter, was observed below Antares . . . altitude about 25°. The body dropped vertically, increasing in brilliancy as it fell, and disappeared about 1° above the horizon . . . visible . . . about 4 seconds . . . clear . . ."

If both times are correct, there are two fireballs in question, but just 59 minutes apart. As neither observer gives seconds, this is practically exactly one hour. Examination of *all* the details shows great similarities. I hence tried the two hypotheses: first that both times should be 0754, second that both should be 0854. The first gives $H_1 = 175 \pm 67$ km, $H_2 = 16 \pm 10$ km; the second $H_1 = 379 \pm 85$ km. As this latter figure is far too high for a beginning point, we adopt the values for hypothesis one. The following data are then derived:

Date	1936 March 25/26, 0754 G.C.T. (March 26)
Sidereal time at end point	218°
Began over	$\lambda = 84°\ 30'$ W, $\phi = 22°\ 36'$ N, at 175 ± 67 km
Ended over	$\lambda = 84°\ 30'$ W, $\phi = 22°\ 36'$ N, at 16 ± 10 km
Length of path	159 km
Projected length of path	0 km (vertical)
Apparent velocity	35.3 km/sec
Radiant (no correction needed)	$h = 90°$; $\alpha = 218°$—, $\delta = +23°$

It should be added that the coordinates used for S2, namely $a_1 = a_2 = 329°$ were measured from a large celestial globe, not computed. Again it must be understood that the solution rests entirely on the hypothesis that the time given at S2 was read just one hour wrong, which is a most unusual error in such reports, unless a clerical one. It is also true that the beginning height computed has a very large deviation of ±67 km. However, everything else points to these being two observations of the same fireball. The solution was made by Miss E. F. Reilly and fully checked by C. P. Olivier.

Fireball of 1938 May 25/26

On this date at 11:26 ± 1 P.M., E.S.T., a splendid fireball was observed from S1, Norwalk, Connecticut, by Joseph Marcus and from S2, Sparkill, New York,

by L. H. Schneider. The object was extremely brilliant, predominantly yellow green in color. It was visible 2 to 4 seconds, leaving an 8-second train. S1 states that it was as brilliant as the full Moon and illuminated the landscape. Also that, facing to west, it went from south to north, *not* near the zenith. Otherwise he gave no coordinates. S2 gives a diagram showing that the body moved in his meridian, through his zenith, from $h_1 = 70°$ to $h_2 = 20°$ in the north. From this we see that the approximate right ascension of the radiant was 234°, but, as no heights can possibly be derived from the data, the declination remains wholly indeterminate. A fireball at 12:10 A.M., E.S.T., was reported from the Br. S. S. Tregarthen, in $\lambda = 74° 29'$ W, $\phi = 36° 27'$ N. From similarities of color, direction of motion, etc., I would infer that this fireball probably belonged to the same radiant as the above.

Fireball of 1941 January 21/22

On this date a bright blue meteor was observed from two ships as follows: S1 "An observer reports that at $8^h 14^m 20^s$ G.C.T. on January 22, 1941, in latitude 38° 01′ 00″ N, longitude 72° 15′ 15″ W, a blue-colored meteor with a long yellow tail was observed which appeared at an altitude of 41°, fell vertically, making a sizzling sound, and burst at an altitude of 12°, bearing 65° (true). When the meteor burst it became red in color and made a crackling sound similar to that of a large piece of timber breaking. It appeared to be very close." S2 by A. C. Barton, 3rd Mate, Am. S. S., Walter Jennings, latitude 35° 19′ N, longitude 74° 59′ W. "On January 22, 1941, 0820 G.M.T. observed a bright bluish-white meteor bearing 48° at an altitude of about 10° traveling in an easterly direction until it disappeared over horizon. Time of observed flight about 6 seconds."

If we assume, as usual, that S1 and S2 *both* saw the beginning point, we derive $H_1 = 181 \pm 41$ km. A diagram of the path *does not* permit a solution for S1 seeing it end (actually said burst) at $h = 12°$ and for S2 to see it pass beyond horizon. The azimuth of the direction of motion is, however, 245° as fixed by the vertical path for S1. I am more inclined to believe that S2 saw a point on path first which was *not* the real beginning point. If so, then we have a point on the path at H = 140 km. This consideration is stressed as it seems to prove that, for this fireball, the upper part of its path was at a considerably greater height than usual. No other certain conclusions can be reached. This date is interesting from the other fireballs reported. This includes one over Maryland at 10:04 P.M., E.S.T.; results published in Popular Astronomy, **50**, 153, 1942. One from New York State at 11:12 P.M., E.S.T., about equal to the Moon. One from Arizona at 10:30 P.M., M.S.T., about equal to quarter Moon. One on January 22/23 at 9:30 P.M., E.W.T., (?), over Virginia; spectacular. Incidentally the path of the one over New York at 11:12 fits excellently the radiant at $\alpha = 99°$, $\delta = +16°$, derived for the Maryland 10:04 fireball.

Fireball of 1941 September 8/9

This fireball which was over New York State can have its radiant, along with other less reliable data on heights, etc., solved if we admit that the observers made a total error of 10 minutes in their times. Internal evidence makes this most probable, but as it is quite impossible to detect *which* is at fault the mean of the two is taken as no appreciable error will result from this procedure. The reports are: S1 by R. W. Canfield, $\lambda = 74° 59'$, $\phi = 40° 43'$, 8:54 P.M., E.S.T., extremely brilliant, blue, fell almost vertically from 1/5 α β Urs. Maj. to horizon in path 5° to vertical sloping to west, slow. S2 by A. G. White, $\lambda = 73° 56'$ W, $\phi = 40°$

48′ N, 9:40:30, P.M., E.S.T., large disc, yellow, fell vertically from 5° south of ζ Urs. Maj., slow. Began at a much higher altitude than Arcturus (then at h = 14° as we calculate) and ceased much lower. Path 10° to 12° long, but probably not all seen.

As Canfield was driving, it is almost certain that he also did not see the beginning point nor would his horizon have been the true horizon. Yet as the path at S2 was vertical and at S1 nearly so, errors in the heights of beginning and end points make little difference in the radiant's position. The following data are derived:

Date	1941 September 8/9, 8:49 P.M., E.S.T.
Sidereal time at end point.	299°.5
Began over	$\lambda = 75°\ 29'$ W, $\phi = 41°\ 44'$ N, at 59 ± 19 km
Ended over	$\lambda = 75°\ 35'$ W, $\phi = 41°\ 47'$ N, at 24 — km
Length of path	40+ km
Projected length of path	7 km
Velocity	Slow
Radiant (uncorrected)	$a = 309°$, h = 75°±; $\alpha = 317°$, $\delta = +30°\pm$

As the radiant's position can hardly be known closer than ±5°, and as it is so near the zenith, it seems useless to put in any zenith correction to the radiant. In any case such a correction would be excessively small. The fireball was evidently outstanding in brilliancy.

Most of the working up of the data was done by Miss E. F. Reilly, the actual results were derived by C. P. Olivier.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1944 May 15.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
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Meteoritical Position Problems

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ABSTRACT

Meteoritical position problems are defined and described in the order of increasing difficulty. A more critical approach to the determination of position data and to the identification of meteorites which have obviously been transported from their places of fall is urged.

Until very recently almost the only concern of the meteorite hunter has been the collection, description, and sale or exchange of specimens. In connection with an analytic study of the distribution of the recognized meteorites of North America[1] the need for much more accurate reporting of the places of find and fall of meteorites soon became evident. Most authors simply assume that the places of fall and find coincide and give only the roughest estimates of their common longitude and latitude, if indeed these coördinates are mentioned at all.

*On leave with the Office of Scientific Research and Development.

In the course of extensive correspondence with county recorders and other public officials, as well as private individuals, corrections amounting to 6° in latitude (Pricetown, Ohio) and nearly a degree in longitude (Sacramento Mountains, New Mexico) were made to positions reported in Farrington's catalog. As a result, material improvement in the concordance between computed and observed distribution was secured. To cite another case in which the need for accurate position reports is paramount, let us consider the problem which arises when we seek to investigate the distribution of "fragments" and/or "outriders[2]" about a meteorite crater. Theoretical predictions as to the nature of these distributions have already been published, *e.g.*, by Gifford,[3] and it has therefore become desirable to secure in the field "place-of-fall" data sufficiently accurate to permit of testing the results of theory. Even the most superficial investigation into the records (or lack thereof) relating to the locations where fragments were found *in situ* about a crater studied as long and intensively as the one at Canyon Diablo, Arizona, will speedily bring the conviction that the field investigator has not been aware of (or at least has not fulfilled) his obligation to provide complete and dependable data for the use of the so-called "armchair meteoriticist."[4] Finally, since the convenient but occasionally ambiguous geographical system of nomenclature for recovered meteorites should obviously be supplemented by an exact, rational system of nomenclature, based on the geographical coördinates of the recovered meteorites, such as that recently proposed by Dr. Frederick C. Leonard,[5] it is evident that even the proper designation of meteorites requires accurate determinations of position.

Consider any *recovered meteorite, M*. Let F denote the place of *fall* and f the place of *find* of M. Then the following problems confront the discoverer of M: (1) Is f identical or nearly identical with F? (2) What are the exact geographical coördinates of f and (in case f differs materially from F) of F? (3) What is the history of the displacement, $\overrightarrow{Ff}$, on the Earth's surface; *i.e.*, what agent or agencies[6] moved M from F to f and in what manner? This ensemble of questions constitutes what may for brevity be described as the "meteoritical position problems" associated with M. However, the third question, except in most unusual cases, now seems to be almost unanswerable, and the second, trivial, at least if M is discovered in a region which has been properly surveyed. Hence, at present, one's chief concern is with questions of type (1). However, the difficulty of questions of type (3) should not be used as an excuse for ignoring them. The importance of a critical study of the possibility that the Anderson, Ohio, meteorite is actually a fragment of the Brenham Twp., Kiowa Co., Kansas, fall should be apparent to meteoriticists as well as to ethnologists. Again, the mystery surrounding the failure of long-continued and intensive search to discover the lost "main mass" of the Port Orford, Oregon, meteorite would at once be dispelled if critical investigation disclosed that, thru unintentional error, the specimen sent by Dr. John Evans to Dr. C. T. Jackson was in reality only a fragment of the original "Pallas Iron" (= Krasnojarsk, Yeniseisk, Siberia, U.S.S.R.) transported from Siberia to Oregon by migrating natives! Obviously, the coöperation of specialists in many fields will be required satisfactorily to solve such fascinating but intractable problems as the pair just described. Moreover, questions of type (2) are by no means trivial if M is discovered in an unsurveyed region or in a surveyed region where section corners have been lost thru the rotting away of trees and posts, the covering up of bench

marks, or the depredations of man. Nevertheless, for such reasons as those earlier emphasized in this paper, the discoverer of a meteorite has an obligation accurately to determine the longitude and the latitude of the place of find, *f*, and also, if possible, of the place of fall, *F*. The difficulty of making such determinations can no longer be offered as an excuse for omitting them. If one has available a transit, a radio, and a good watch, a point of find can be located to within approximately a quarter of a mile by methods now habitually employed, *e.g.*, by field artillerymen.[7] The exceedingly ingenious instrument for celestial navigation, recently devised by Storer,[8] with which both the latitude and the sidereal time are read directly from dials after a single setting on the sky, with a probable error in one setting of about 0°.1 in both coördinates, offers prospects of a most satisfactory solution of problems of type (2), from the viewpoint even of the overburdened meteorite hunter!

It is the purpose of this article to give an account of various "meteoritical position problems" of the first type encountered in the field. These problems are taken up in the order of increasing difficulty, and suggestions which may aid in their solution are made.

FIG. 1
THE DEEPLY BURIED ECTOR COUNTY, TEXAS, SIDERITE

Under certain favorable circumstances, the field investigator can have no reasonable doubt that the place of fall and the place of find are the same. In the case of an authentic witnessed fall like Farmington, Kansas, the question simply does not arise. In the case of unwitnessed falls, mere size may at once supply an answer, as in the case of Bacubirito, Sinaloa, Mexico, altho knowledge of the "excursion" on which such a giant as Willamette, Oregon, was taken by the most primitive mechanical means[9] will always urge caution in accepting mass alone as a criterion of immovability! The identity of places of fall and find is assured when a meteorite is found in an impact hole, as was the St. Michel, Finland, meteorite, or in a shallow impact crater, as was the Huckitta Station, Central Australia, meteorite, or even when near a mere indentation in the Earth, matching the shape of the meteorite, as was true for one of the stones of the Bath Furnace, Kentucky, fall. Again, deeply buried meteorites found by instrumental search, like the Ector County, Texas, iron, so firmly "welded" into its rock target that a

house-jack had to be used to break it loose (see Fig. 1) and the "accordion meteorite," located at the Odessa, Texas, Crater by the First Ohio State University Meteorite Expedition,[10] were certainly "in place"! In support of this conclusion we can cite not only the observed penetrations but also such additional impact effects as pronounced metamorphism of the country rock in which the meteorites were imbedded. As regards instrumental finds, it is, of course, unnecessary that the meteorites should be actually "fused" into the rock target, as in the case of the last two examples cited, before one is in a position to assert the identity of *F* and *f*. Indeed, unless the field investigator uncovers evidence that the meteorite has been interred by man (as in the case of the Plymouth, Indiana, iron[11]) or other agencies, such identity may safely be assumed for all *buried* meteorites found by instrumental scarch.

Fig. 2

A Partially Exposed Odessa, Texas, Iron

A position problem of greater difficulty arises in the case of *surface finds*, where neither association with an observed fall, nor size, nor evidence of impact testifies as to the identity of the place of find and the place of fall. As interest in and familiarity with meteorites develop, the number of such surface finds will steadily increase. The range of subcases encountered in this category is very large. At the one extreme we have surface finds like that of the large Odessa, Texas, iron shown in Fig. 2. Here the meteorite, found without instrumental aid, extended downward among broken fragments of rock, metamorphosed

very slightly if at all, which had lain undisturbed so long that the whole breccia-like mass of meteorite and rock was solidly cemented together. Furthermore, the visible portion of the meteorite projected from a compacted layer of soil bearing a mature stand of slow-growing desert plants and grasses. Consequently, there can be little doubt that this Texas iron lay precisely at the spot where it originally fell. An intermediate case is that of the Casas Grandes, Chihuahua, Mexico, octahedrite. Were it not for the large mass of this meteorite, one would have perhaps no hesitation in asserting that it had been moved by human agency into the ancient "Montezuma temple ruins." However, on the basis of the information available, it appears quite as likely that the temple was in reality built about the meteorite! At the other extreme of surface finds, we find such a case as Tomhannock Creek, Rensselaer Co. (= Yorktown), New York, where there seems to have been initially no cause to question the good faith of the finder, but where the most expert testimony points to a place of fall (Homestead, Iowa), a thousand miles from the reported place of find!

Finally, we have the very difficult position problems which arise when it is perfectly evident that the place of find is *not* the place of fall and where the circumstances are such as to render most uncertain any determination of the latter place. The most recent example to be added to the accounts of such finds, many of which occur in meteoritical literature, is that of the stone found in 1943 in northern Cowley County, Kansas.[12] This stone was obviously not *in situ*, and, in view of its small size and light weight, it *may* have been carried by man over very great distances before being finally discarded and then picked up again on a Kansas farm. A classic example of the displacements a meteorite may experience in the hand of man is that of the Enon, Ohio, mesosiderite, which was carried by its finder from Ohio to Iowa, Colorado, Wyoming, and Utah, and back to Colorado, before its meteoritic nature was finally recognized.[13] It is easy to imagine circumstances under which Enon might have been credited to *any one* of the States just named. Only the fortunate survival of its finder permitted a determination of its true place of fall.

With the Enon meteorite and other similar cases in mind, two things become strikingly evident: *first*, unless there is convincing evidence that a meteorite has *not* been moved from its place of fall, its finder has a personal responsibility to incorporate into the literature an explicit statement of his uncertainty as to where it fell and complete details of all evidence that might be useful in determining the actual place of fall; and, *second*, a meteorite found under such circumstances as the Cowley Co., Kansas, stone should *not* be hastily declared to represent a *new* fall merely because it is regarded as distinct from all known falls within such a circumscribed radius as 50 miles. On the evidence of no less an authority than Brezina, Tomhannock Creek was very probably *not* a new fall, altho it would have been necessary to go outside a circle of radius *one thousand* miles in order to find the strewn field on which this specimen fell!

In the writer's opinion, positive identification of a given meteorite as a member or a non-member of a certain fall is a much more difficult task than statements often made in the literature would indicate. The range, both as to chemical composition and as to structure, observed in specimens of the same fall may be surprisingly large, so large, indeed, that, were it not for foreknowledge of the fact that two members fell together, these members might easily be assigned to distinct falls. On the other hand, those who, *e.g.*, do not share Brezina's views concerning the identity of Tomhannock Creek (= Yorktown), New York, and

Homestead, Iowa, can argue that members of two widely separated falls may be almost identical.

It may be possible to avoid the distressing uncertainties now encountered in identification work by making use of such modern procedures for exact age-determination as the *helium method* or for differential age-measurements as the *activity-ratio method*. We should expect such methods to demonstrate that all of the masses recovered from the same fall, *e.g.*, those of the Brenham Twp., Kiowa Co., Kansas, or of the Gibeon (= Bethany), Great Namaqualand, South Africa, showers, were of the same age, irrespective of structural and chemical differences, while two specimens of distinct falls, no matter how nearly identical otherwise, would be expected, in general, to show age differences, unless they were known, from orbital considerations, to belong to the same space-stream of meteorites.

NOTES AND REFERENCES

[1] L. La Paz, *C.S.R.M.*, **2**, 172-88; *P. A.*, **48**, 157-65, 205-12, 1940.

[2] On the basis of observations made in the course of the survey of the Odessa, Texas, Crater by the First Ohio State University Meteorite Expedition, in 1939, we are led to distinguish between "fragments" thrown out in parabolic paths by the explosion which occurred when the main mass struck the Earth and "outriders," *i.e.*, smaller, companion meteorites which trailed along beside or behind the main mass in its orbital motion. The "fragments," irrespective of their weight, were found buried at nearly the same depth below the surface of the ground; on the contrary, the depth of penetration of the "outriders" was roughly a linear function of the cube root of the mass, as predicted by the penetration theory developed by the writer (see L. La Paz, *Astron. Nach.*, **267**, 107-12, 1939).

[3] *Cf. New Zealand Jour. Sci. & Technol.*, **7**, 137, 1926.

[4] The record of "places of find" of Canyon Diablo meteorites and shale balls, given by Barringer and Tilghman in their various papers, constitutes a notable and welcome exception. The writer has little doubt that if an equally comprehensive and reliable record of the places of find of the iron masses of the Gibeon (= Bethany), South Africa, shower were available, it would be possible to present evidence strongly supporting the hypothesis that the Crater of the Geitsi Gubib is a meteorite crater.

[5] F. C. Leonard, *C.S.R.M.*, **2**, 270; *P. A.*, **49**, 214-15, 1941.

[6] An exhaustive enumeration of possibilities here is out of the question. However, in addition to transportation of meteorites effected in many ways by man, one may mention displacements occasioned by stream action, by land slides, and by the motion of ice sheets. In the latter case, we should distinguish between meteorites which fell onto the ice sheet and were carried forward, while buried in it, and those fallen meteorites which were torn up by the gouging action of an overrunning ice sheet and were then pushed forward by its advancing edge. A specialist in the surface features of meteorites should be able to determine to which subclass a given meteorite belongs.

[7] Captain Robert Amory, Jr., *Field Artillery Jour.*, **32**, No. 11, 818-27, 1942.

[8] N. Wyman Storer, *Jour. Aeronaut. Sci.*, **9**, No. 4, 138-40, 1942.

[9] O. C. Farrington, *Mem. Natl. Acad. Sci.*, **13**, 490-4, 1915; J. H. Pruett, *C.S.R.M.*, **2**, 85-7; *P. A.*, **47**, 148-50, 1939.

[10] L. La Paz, Fig. 3, *C.S.R.M.*, **3**, 15; *P. A.*, **50**, 163, 1942.

[11] O. C. Farrington, *Mem. Natl. Acad. Sci.*, **13**, 355-6, 1915. Meteorites which are found undisturbed in the position taken up when they penetrate deeply into the Earth are observed usually to have a characteristic orientation. The "accordion meteorite," referred to in ref. ([10]), *ante*, is the best example of this sort known to the writer, but other striking illustrations could be given. On the contrary, a meteorite which has suffered *burial* at the hand of man, or has been otherwise disturbed, is unlikely to preserve the orientation which it had when it penetrated into the Earth. In addition to this *orientation criterion*, the meteoriticist may find also the following *penetration criteria* of use: deep penetration into the Earth

seems to be accompanied always by metamorphic effects; on the contrary, such effets do *not* occur, no matter how deeply a meteorite has been *buried* or *otherwise covered up* in the Earth. Again, except in the case of "fragments," the depth of penetration is proportional to the cube root of the mass; no such law governs depth of burial.

[12] H. H. Nininger, *C.S.R.M.*, **3**, 123-4; *P. A.*, **52**, 42-3, 1944.

[13] H. H. Nininger, *C.S.R.M.*, **3**, 61-3; *P. A.*, **50**, 563-5, 1942.

On the Assignment of Co-ordinate Numbers to Meteoritic Falls

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ABSTRACT AND INTRODUCTION

The preceding paper by Dr. Lincoln La Paz on "Meteoritical Position Problems" raises some interesting questions concerning the assignment of coördinate numbers[1] to meteoritic falls. These matters are briefly discussed in the following paragraphs. There is an addendum on the observational determination of the coördinates of a place.

(1) The coördinate number of a fall should be composed of the geographical coördinates (*i.e.*, the longitude and the latitude, each correct to the closest tenth of a degree) of the actual place of fall, *F*, whenever this is known.[2] It is known generally in the case of a witnessed fall.

The famous Holbrook, Arizona, aerolitic shower of 1912 July 19 occurred not within the "city limits" or even within the immediate vicinity of the town of Holbrook, but at a point on the Santa Fe Railroad about 6½ miles east-northeast of Holbrook, named Arntz. The coördinate number of Arntz is 1100,349, while that of Holbrook is 1101,349; hence, the coördinate number of the so-called Holbrook shower is 1100,349, not 1101,349.[2]

(2) If the place of fall, *F*, is not known but may reasonably be assumed to be identical with the place of find, *f*, which is known, the coördinate number of the fall should be evidently the coördinate number of the place of find, *f*.[2]

(3) If the place of fall, *F*, is not known and the place of find, *f*, is known, but the two places are obviously not identical, the coördinate number of the fall should be the coördinate number of the place of find, *f*, followed by the letter *f*, thus: 1107,350*f* (1107,350 is the coördinate number of Winslow, Arizona, used here simply as an illustration).[2]

(4) If the place of fall, *F*, is not known and the place of find, *f*, is known only approximately and the fall has received the name of the post office or landmark nearest to the *assumed* place of find, or the name merely of the county (or some such political subdivision) in which the fall was found, the coördinate number adopted for the fall should be the coördinate number of the place or natural feature from which the fall has derived its name, followed by a colon (:), thus: 1051,398: (the coördinate number of the doubtfully located Bear Creek, Jefferson County, Colorado, siderite).[2]

If the name of the fall is the name simply of a county (or some such political subdivision), "the place," for the purpose of evaluating the coördinate number, should be taken to mean the county seat (or local capital town); *e.g.*, the coördinate number of the recently reported Cowley County, Kansas, aerolite[3] is 0970,372: (0970,372 being the coördinate number of Winfield, the county seat of Cowley County).

(5) In the case of a multiple fall or shower, which may be defined as a fall consisting of 2 or more complete individual meteorites, the coördinate number should be that of the geometrical center of the area over which the fall occurred.[2] That it may be difficult, if not impossible, exactly to locate the geometrical center of the area of the fall is, of course, quite beside the point of the present discussion.

REFERENCES AND NOTE

[1] F. C. Leonard, *C.S.R.M.*, **2**, 270; *P. A.*, **49**, 214-15, 1941.

[2] Irrespective of the geographical designation of the fall, which, save in a very exceptional case, should be the name of the nearest post office or prominent landmark, whichever is the nearer, within a distance of 3 or 4 miles, to the place of fall, *F*, if this is known, or to the place of find, *f*, if the place of fall, *F*, is not known. See F. C. Leonard, *C.S.R.M.*, **2**, 64 and 155-6, 1938-41; *P. A.*, **46**, 581-2, 1938, and **47**, 566-7, 1939.

[3] H. H. Nininger, *C.S.R.M.*, **3**, 123-4; *P. A.*, **52**, 42-3, 1944.

ADDENDUM: ON THE OBSERVATIONAL DETERMINATION OF THE COÖRDINATES OF A PLACE

Probably the simplest way observationally to determine the coördinates of a place is to measure (with a sextant, a surveyor's transit, or some other portable instrument) the Sun's maximum (meridian) altitude, which occurs evidently at the instant of local apparent noon, and to note the *Greenwich Civil Time* (G.C.T.) corresponding to that instant, which will be designated by G. The longitude L of the place is, then,

$$L = G + E - 12^h,$$

where E is the equation of time (in the sense of apparent time minus mean time), and the latitude l is

$$l = \delta \mp h \pm 90°,*$$

where δ is the Sun's apparent declination and h is the maximum (meridian) altitude of the center of the Sun's disk. The values of E and δ, at the instant G, are to be obtained from an almanac, while the observed altitude of the Sun's upper or lower limb must be corrected for atmospheric refraction and for semidiameter (which, to the closest minute of arc, equals 16′), in order to evaluate h. The correction for the Sun's diurnal or geocentric parallax, which amounts at its maximum to only 8″.8, is of course wholly inappreciable with an ordinary field instrument.

A Note on the Origin of the Lunar Craters

The prevailing scientific opinion seems to be that there are two sorts of craters on the Moon—those that are of intrinsic or explosive origin and those that are of extrinsic or meteoritic origin. Under the first category would come not only typically volcanic craters but also "blowout" or "burst-bubble" craters, *i.e.*, craters that "have been formed by the bursting out of great masses of gas which gathered under the surface of the Moon and became heated and subject to great tension because of its contraction" (F. R. Moulton, *An Introduction to Astronomy*, New & Rev. Ed., p. 213, 1916).

If the lunar craters are of these three varieties, a simple criterion that might

*The upper signs are to be used when the Sun and the celestial equator are on the same side of the zenith; the lower signs, when they are on opposite sides of the zenith.

conceivably be employed to distinguish the typically volcanic craters on the one hand from the blowout and the meteoritic craters on the other is the presence in, or the absence from, a crater of one or more central peaks. Possibly the craters that possess central spires, especially peaks with surmounting craterlets, are in general of typically volcanic origin, while those that are devoid of central mountains—many of which bear a striking resemblance in shape, if not also in size, to the Canyon Diablo, Arizona, Meteorite Crater—are, for the most part, either of meteoritic origin or the remains of burst bubbles. Whether an additional criterion can be found, whereby the blowout craters can in turn be differentiated from the meteoritic, is a moot question. In any event, that there are several kinds of craters on the Moon appears to be highly probable; therefore, the volcanic hypothesis, the burst-bubble hypothesis, and the meteoritic-bombardment hypothesis may, all three, be concurrently applicable to the problem of explicating their genesis.

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VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Trends in the Study of Eclipsing Binaries: Within very recent years the study of eclipsing variables has made rapid progress, and the investigations have included a wide variety of stellar objects. There are to be found representatives of all spectral classes among these stars, from W to M, with the exception of classes N, R, and S. Instances have been noted of eclipsing stars with one or more components intrinsically variable, as for example VV Cephei, ζ Aurigae, RX Cassiopeiae, and W Serpentis. The Milton Bureau of Harvard has paid particular attention to this type of variable, and we are indebted to Drs. S. and C. Payne-Gaposchkin for the following notes.

The eclipsing stars ϵ Aurigae and ζ Aurigae provide examples for the study of stellar envelopes about supergiant eclipsing variables, and five more such stars have been added to the list.

Star	Period[a]	Spectrum	Discoverer of Eclipsing Nature
VV Cephei	7430	M2 and B9	S. Gaposchkin
S Doradus	14670	P Cygni	S. Gaposchkin
AR Pavonis	605	P Cygni	Mrs. Mayall
V381 Scorpii	6505	F5 ?	Miss Swope
V383 Scorpii	4900	..	Miss Swope

Of these five, only VV Cephei has so far been studied spectrographically, and although such variables may not be numerous, there is a good chance of their detection, especially among stars with composite spectra—with early and late type components.

Three more β Lyrae systems have been found from a combination of photo-

metric and spectrographic work.

Star	Period d	Spectrum	Spectrographic Results
UW Canis Majoris	4.3934	O 9.5 e	Luyten and Ebbighausen, Struve
V453 Scorpii	12.004211	O e 5	Humason and Nicholson, Struve
RY Scuti	11.124939	O e	Merrill, Popper

Recent investigations reveal that for each of these three β Lyrae-type stars, the spectrum of the second component is not visible, and that an extensive envelope, similar to that shown to exist for β Lyrae, probably surrounds each star.

There are indications that the bright lines of UW Canis Majoris show a red shift, of interest when compared with a similar condition found in the W component of V444 Cygni.

Two Wolf-Rayet eclipsing binaries are now known:

Star	Period d	Spectrum	Spectrographic Results
V444 Cygni	4.21238	W N 5.5 and O6	O. C. Wilson, Beals
HD 214419	1.6410	W N 6	McLaughlin, Hiltner

The first variable has an Algol-type light curve, but with minima of very different widths. The second variable has a β Lyrae-type light curve, with an amplitude of 0^m34, and the components are very close together, which must of necessity place some restrictions on the size and distribution of the envelope of the W star. The period of this star is also slightly variable.

Those eclipsing binaries with W components have introduced new problems into the discussion of their light curves. It is clearly evident from the form of the minima of V444 Cygni that the customary picture of uniform or moderately darkened discs is applicable only in a very general form. The problem of the thick expanding atmosphere, as discussed by Kosirev and Chandrasekhar, gives a better picture of the darkening to be expected, and the extremely darkened disc, of which use has already been made in the interpretation of the expanded phases of novae, is found to give the type of eclipse that is observed for V444 Cygni. In these stars it is accordingly evident that the simple conception of a stellar disc is no longer tenable, and that a deep envelope with properties that differ with wave-length, must be envisaged.

But the W-type stars are not the only eclipsing stars whose deep envelopes lend themselves to detailed study. For example the super-giants SX Cassiopeiae and RX Cassiopeiae have recently been discussed spectrographically by Struve, and supplemented by photometric work on Harvard plates. The effects of envelopes appear, for both stars, in a dependence of photometric results on wavelength, the blue component being apparently smaller in photographic light than in visual light. Here is presented another aspect of the exaggerated darkening produced by the envelope, and opens up new possibilities in the interpretation of the light curves of giant eclipsing systems when observed in two different wavelengths.

The photographic light curve of RX Cassiopeiae shows some remarkable features. There is a regular over-all variation of average brightness (with a period of 517 days) that is attributable to the variation—to the extent of a half-magnitude—of the blue A5 component; the other component is a class G3 star. The maximum which follows the primary minimum is decidedly brighter than the other maximum, which seems to be interrupted by an irregular, additional minimum not long before primary minimum occurs. These features are of par-

ticular interest when compared with those revealed in the light curve of the eclipsing binary W Serpentis. This star shows an over-all variation of the light curve, a high primary minimum, with apparently two secondary minima, a spectrum not unlike that of RX Cassiopeiae, and indeed W Serpentis appears to show the peculiar behavior of the latter star in an exaggerated form.

Two other stars which show conspicuous over-all changes of light curve, not hitherto shown to be periodic, are GG Carinae, and AR Pavonis, studied respectively by Miss Hoffleit and Mrs. Mayall from Harvard plates.

There is apparently a new and large field of research opening up for eclipsing stars with greatly extended atmospheres, closely linked with the current work of Struve, his collaborators, and others, on the spectra of stars with deep envelopes.

Notes on Individual Variables: Three of the SS Cygni-type stars have been at maximum recently. *U Geminorum* was observed early in May by T. C. H. Bouton to be on the rise to maximum, and a day or two later actually at maximum, as observed by D. W. Rosebrugh. This is the only observed maximum noted since that of September, 1943. *SS Aurigae* was also at maximum about April 10, evidently of the short, narrow type. *X Leonis* was at maximum about April 12.

Of the R Coronae Borealis-type variables, *SU Tauri* remains faint, below magnitude 13.5, and should be carefully watched later in the morning sky in order that its increase to maximum, when it does occur, may not escape attention. *R Coronae Borealis* itself is at normal maximum brightness, magnitude 6.0; a condition which has existed for the past year. *RY Sagittarii* is also back at full maximum brightness, magnitude 6.5. No recent observations of *S Apodis* have come to hand, but when last observed, early in the year, it was of approximately the twelfth magnitude.

Observations: Summary of observations, as contributed during the month of April, 1944, by 35 observers, is given below.

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Bappu	34	52	Mary	14	14
Boone	8	8	Meek	35	169
Bouton	26	30	Nadeau	38	44
Backstaff	6	7	Oheim	19	31
Chandra	148	189	Oravec	2	4
Cousins	35	85	Parks	16	24
Fernald	133	189	Peltier	148	193
Ford	14	15	Robinson	44	94
Garneau	25	28	Rosebrugh	30	210
Gaposchkin	22	22	Schoenke	20	29
Hartmann	103	107	Sill	54	54
Holt	69	78	Topham	26	28
Houston	15	32	Vohman	18	36
Howarth	17	17	Webb	8	8
Kearons	61	65	Weber	68	129
Kelly	12	13	Wolfram	7	9
de Kock	56	275	—		—
Kooms	17	17	35	(Totals)	2310
Mayberry	5	5			

May 22, 1944.

Comet Notes

By G. VAN BIESBROECK

During the month of May two new comets have been announced.

COMET VÄISÄLÄ. The first was found by Y. Väisälä at Turku (Finland) who previously discovered the comets 1939 *b* and 1942 *c* by means of his very efficient large-field reflector. No date of discovery was given in the telegram which came through Sweden, the only information forwarded being the predicted position for three dates:

1944	h m	° ′
May 14	12 38	—0 29
May 22	36	—0 51
May 30	12 35	—1 20,

and the mention that the magnitude is 15. Cloudy skies and later moonlight have interfered here with observation of this small object situated in the constellation of Virgo. No further information has been received to date concerning the comet which will probably remain very faint.

COMET DU TOIT. Within less than a week another discovery was transmitted through the Harvard College Observatory, Cambridge (Massachusetts). It came from its southern station at Bloemfontein in South Africa, and was made by D. du Toit, who is on the staff of that active observatory. Mr. du Toit's name is familiar in comet literature as the discoverer of COMET 1941 *c*. His new comet was first seen on May 16. The following later information was given by the Bloemfontein Observatory:

1944 May 25 at 0^h U.T.
Right ascension $21^h\,4^m$, Declination $-63^\circ\,44'$
Magnitude about 10
Daily motion 9^m east and 14′ south.

The motion indicates that for some time this object will be visible only at the southern stations. But there is no way of telling from these data what the future course of the comet will be, it may well brighten up and move into a more favorable situation for observers north of the equator.

The following parabolic orbit for COMET DU TOIT, computed by Bobone at the Cordoba (Argentina) Observatory has just been received:

Time of Perihelion 1944 June 10.571 U.T.		
Node to perihelion	247°18′	1943.0
Longitude of node	37 18	
Inclination	20 47	
Perihelion distance 1.3215 Astr. Units.		

They show that the comet will increase somewhat in brightness but remain far south for several months.

It is not possible to give these two recent discoveries a designation by letter as long as the exact date of discovery has not been published.

Aside from these newcomers no less than four faint periodic comets have been under observation this spring:

PERIODIC COMET COMAS SOLÁ is approaching the end of its visibility in the evening sky. Already on March 15 it was at low altitude after twilight but it was still recorded here as a well-condensed coma with a short tail opposite to

the direction of the sun. The brightness corresponded to magnitude 14.

PERIODIC COMET DANIEL 1909 IV has been recorded by Väisälä on January 18 and this confirms the previous recovery by G. F. Kellaway on November 30. From these data it was possible to compute the location in October last year at the time when the writer took plates of the field with the 82-inch reflector of the MacDonald Observatory. The object was recognized, on a pair of plates taken October 23, as a fuzzy trail unfortunately quite close to the edge of the plate. In brightness it was then of about magnitude 15. The location is still favorable in the western sky but the comet is probably extremely faint by now.

PERIODIC COMET SCHAUMASSE, which was missed several times by the writer this winter, has fortunately been recovered on large-field plates at the Lowell Observatory by H. L. Giclas, taken on March 24, 29, and 30. The comet appeared diffuse but had a central nucleus. The magnitude was estimated as 15. It was observed nearly seven degrees away from the predicted position, which corresponds to a delay of 23 days in the time of perihelion passage computed by M. Sumner. Subsequently the comet has been recorded several times by C. H. Herbig at the Lick Observatory. He writes that in May the comet appeared as a small, well-condensed coma, 6″ in diameter and of magnitude 17.5. While the field of this comet is still conveniently located in Libra the extreme faintness will soon put an end to the visibility.

PERIODIC COMET OTERMA 1943 *a*. This faint object, remarkable on account of the small eccentricity of its orbit, has been kept under observation this spring. When last recorded here on May 29 it still had the same appearance of a small round coma of magnitude 16. So far no appreciable change has been noticed in the brightness of this comet, which evidently can be followed all around its orbit described in eight years.

Thus all the periodic comets expected recently have been accounted for. The next one expected is the SHORT PERIOD COMET ENCKE which comes to perihelion August 7. However the conditions of visibility will remain very poor at this return. The angular separation from the sun will not exceed 30 degrees toward the end of June after which the comet will be lost in the glare of the sun. In September the conditions become more favorable but only for southern observers.

The variable COMET SCHWASSMANN-WACHMANN 1925 II will emerge from daylight in the morning sky next July. P. Herget gives the following improved ephemeris:

1944		(1950.0) h m	° ′
July	9	3 12.0	+26 53
	25	20.6	27 44
Aug.	10	27.1	28 29
	26	31.3	29 8
Sept.	11	32.6	29 38
	27	3 31.0	+29 58,

showing that it will be well located for northern observers.

Williams Bay, Wisconsin, 1944 June 2.

Correction: In the first line of the last paragraph of the article on the occultation of Jupiter, on page 255 of the preceding issue, one should read "bright limb of the moon," instead of "dark limb of the moon." ED.